The TREND

IN ENGINEERING

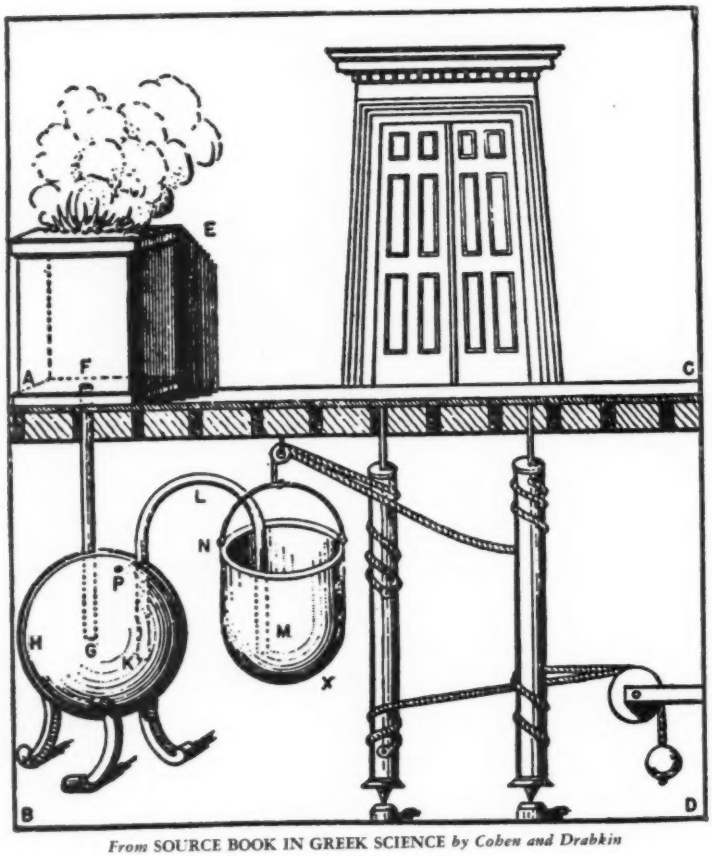
at the University of Washington

In This Issue

- Hydroelectric Power in the Northwest
- Educating the Whole Man
- Lateral Buckling of Simply-Supported I-Beams
- Separation of Amino Acids by Ion Exchange
- The Electron Diffraction Camera
- Triethylene Glycol as a Painting Agent and Solvent for Lignin
- Photoelastic Stress Analysis of a Turbine Rotor
- The Two-Year Graduate Degree in Engineering
- Mechanics of Snow Accumulation on Highways

July, 1950

VOL. 2, No. 3



From SOURCE BOOK IN GREEK SCIENCE *by Cohen and Drabkin*

Automatic Opening of Temple Doors

THE CONSTRUCTION of a small temple such that, on lighting a fire, the doors shall open spontaneously, and shut again when the fire is extinguished. Let the proposed temple stand on a pedestal, ABCD (see fig.), on which lies a small altar, EA.

Through the altar insert a tube, FG, of which the mouth F is within the altar, and the mouth G is contained in a globe, H, reaching nearly to its centre: the tube must be soldered into the globe, in which a bent siphon, KLM, is placed. Let the hinges of the doors be extended downwards and turn freely on pivots in the base ABCD; and from the hinges let two chains, running into one, be attached, by means of a pulley, to a hollow vessel, NX, which is suspended; while other chains, wound upon the hinges in an opposite direction to the former, and running into one, are attached, by means of a pulley to a leaden weight, on the descent of which the doors will be shut. Let the outer leg of the siphon KLM lead into the suspended vessel; and through a hole, P, which must be carefully closed afterwards, pour water into the globe enough to fill one half of it. It will be found that, when the fire has grown hot, the air in the altar becoming heated expands into a larger space; and, passing through the tube FG into the globe, it will drive out the liquid contained there through the siphon KLM into the suspended vessel, which, descending with its weight, will tighten the chains and open the doors. Again, when the fire is extinguished, the rarefied air will escape through the pores in the side of the globe, and the bent siphon (the extremity of which will be immersed in the water in the suspended vessel) will draw up the liquid in the vessel in order to fill up the void left by the particles removed. When the vessel is lightened the weight suspended will preponderate and shut the doors. Some in place of water use quicksilver, as it is heavier than water and is easily disunited by fire."

—Heron of Alexandria (150-100 B.C.?), *Pneumatica*, I, 38. Translation of J. G. Greenwood. From SOURCE BOOK IN GREEK SCIENCE by Cohen and Drabkin. Copyright, 1948. Courtesy of McGraw-Hill Book Company.

THE ENGINEERING EXPERIMENT STATION of the University of Washington was established in December, 1917, to coordinate investigations in progress and to facilitate the development of engineering and industrial research in the University. Its purpose is to aid in the industrial development of the state and nation by scientific research and by furnishing information for the solution of engineering problems.

The scope of the work is three-fold:

(1) to investigate and publish information concerning engineering problems of a more or less general nature that would be helpful in municipal, rural, and industrial affairs;

(2) to undertake extended research and to publish reports on engineering and scientific problems;

(3) to provide opportunities for graduate engineers to conduct research under conditions that will most effectively prepare them for professional service.

For administrative purposes the work of the Station is organized into nine divisions:

1. Aeronautical Engineering
2. Chemical Engineering, Industrial Chemistry
3. Civil Engineering
4. Electrical Engineering
5. Forest Products
6. Geology
7. Mechanical Engineering
8. Mining, Metallurgy, Ceramics
9. Physics Standards and Tests

The control of the Station is vested in a Station Board consisting of the President of the University, the Dean of the College of Engineering as chairman, the Director of the Station, and members of the faculty, representative of the administrative divisions. The Board determines the character of the investigations to be undertaken and supervises the work.

The Station offers a substantial number of research fellowships to highly qualified graduate students who work under the direct supervision of the faculty of the various divisions. The results of the investigations are published in the form of bulletins, technical notes, and reports. Reprints of articles by members of the engineering faculty and graduate students published in recognized technical journals are also issued by the Station. Requests for copies of the publications and inquiries for information on engineering and industrial problems should be addressed to the Director, Engineering Experiment Station, University of Washington, Seattle 5.

July, 1950

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Vol. 2 No. 3

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CONTENTS

Hydroelectric Power in the Northwest
Floyd D. Robbins 5

Educating the Whole Man
Stuart W. Chapman 10

Lateral Buckling of Simply-Supported I-Beams
N. C. Cyr, R. A. Hechtman 13

Separation of Amino Acids by Ion Exchange
Z. E. Carey, T. D. Toomey, A. E. Markham, J. L. McCarthy 17

The Electron Diffraction Camera
Oliver Row 21

Triethylene Glycol as a Pulping Agent and Solvent for Lignin
B. L. Grondal, P. Zenczak 24

Photoelastic Analysis of a Turbine Rotor
E. E. Day 26

The Two-Year Graduate Degree in Engineering
W. Ryland Hill 27

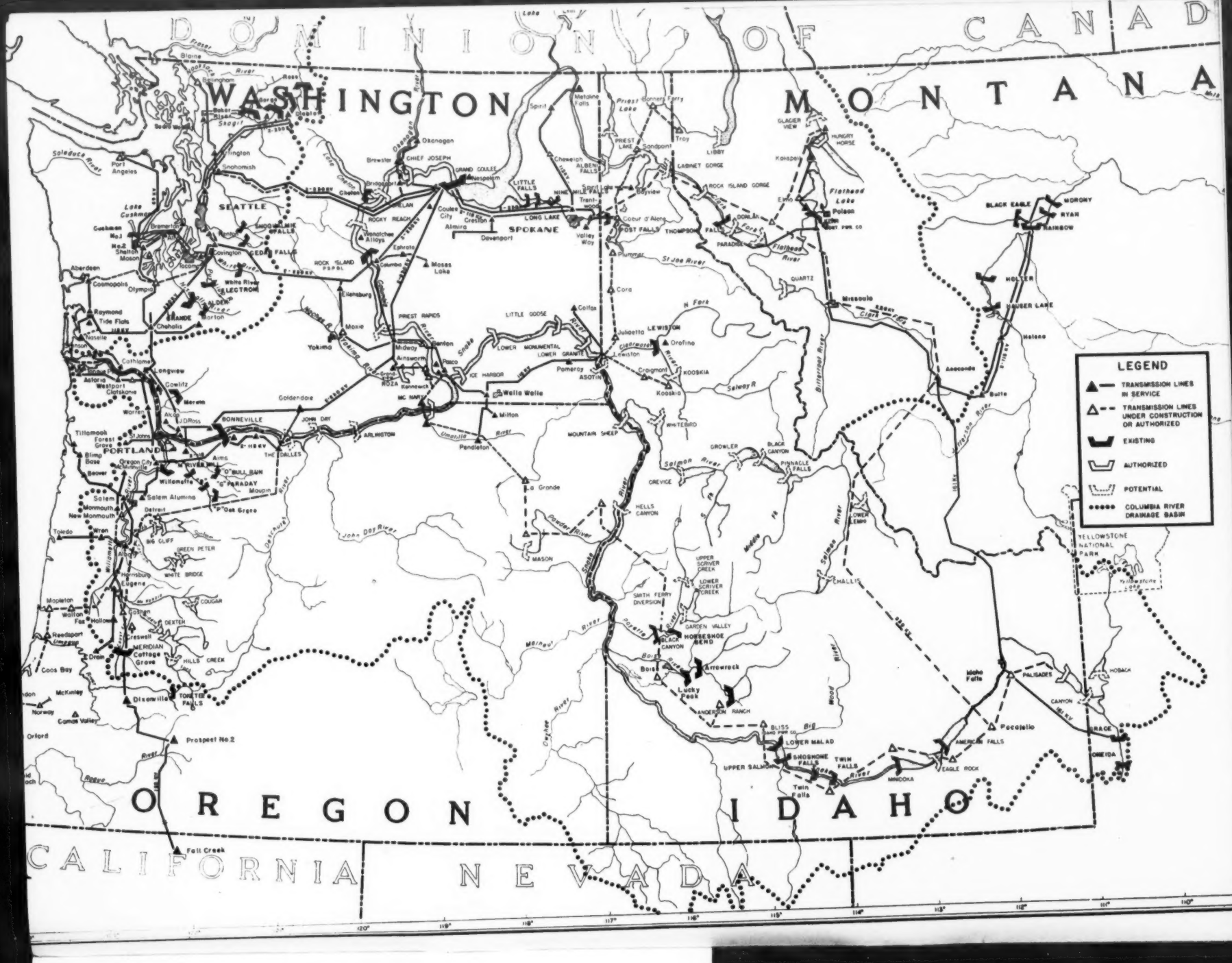
Mechanics of Frost Action on Highways
R. H. Meese 28

The University Research Foundation 30

Hill and Dwinnell Author Texts 31

COVER

Photograph by Bonneville Power Administration, taken on the Goldendale- Coulee main line (230,000-v) in Klickitat County, August, 1941, at 7 p.m. The photographer had his camera wide open before the storm struck, anticipating the lightning.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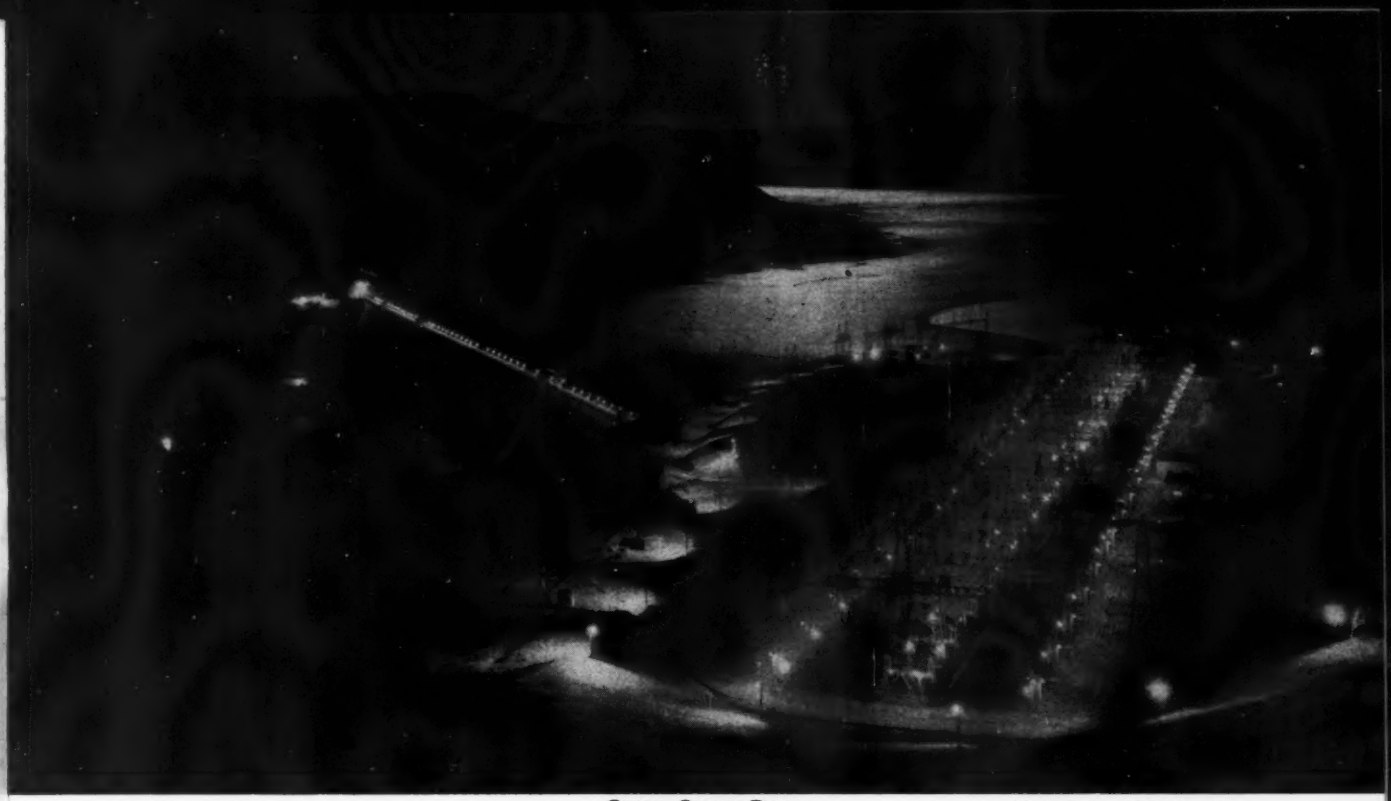


GRAND COULEE DAM *Photo, Bureau of Reclamation*

HYDROELECTRIC POWER IN THE NORTHWEST

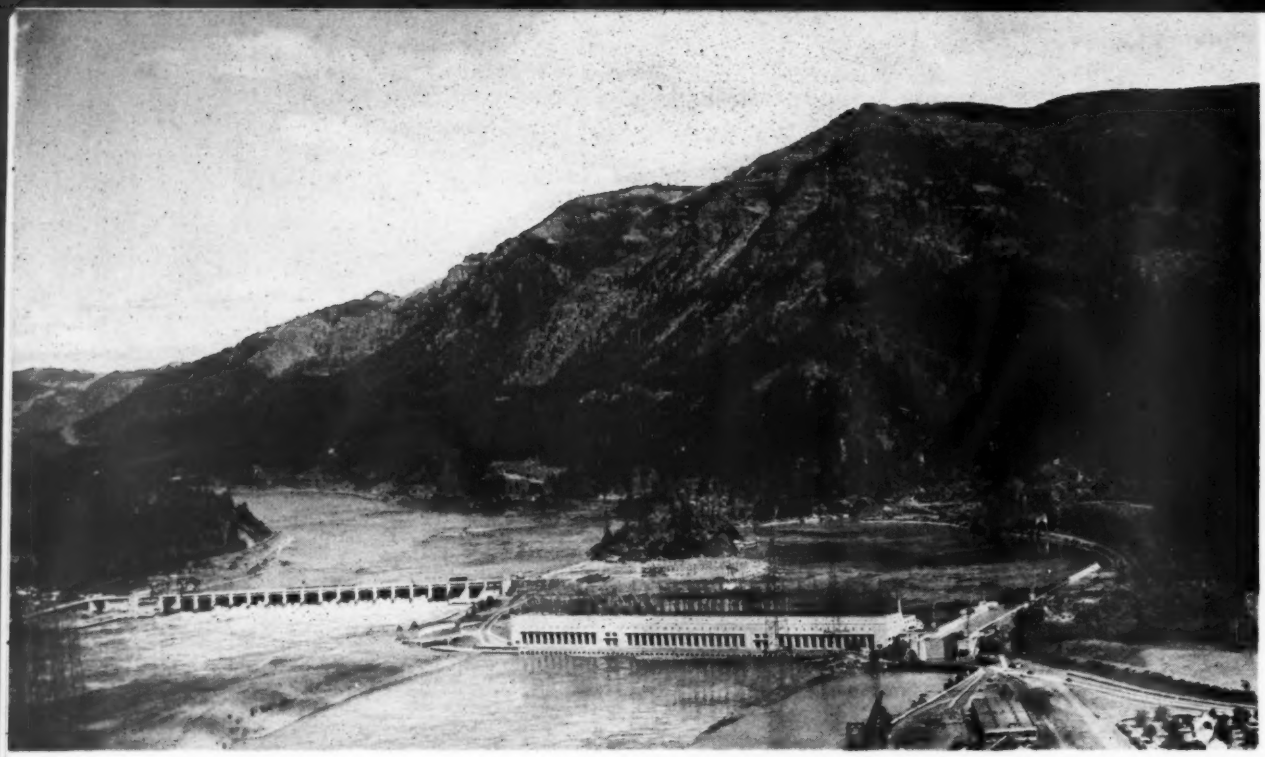
FLOYD D. ROBBINS
Instructor in Electrical Engineering

F. D. Robbins

Ages ago, the bed of the early Cretaic sea which covered what is now the states of Washington, Oregon, Montana, and Idaho, underwent a series of tremendous upheavals which continued, interspersed with periods of volcanic activity, glacial ice sheets, and roaring floods, for perhaps as long as 100 million years. Out of this geological activity emerged the Rockies, the Cascades, the Olympics, and the Columbia Basin, a region of vast forests, deep canyons, high snowy peaks, great glaciers, and scores of turbulent rivers. It is a region whose wealth of mineral treasures is practically untouched and includes basic raw materials for the light-metals industries. It is a region whose area (17 per cent of the land area of the United States), includes millions of acres of rich but arid land awaiting only the miracle of irrigation. It is a region, most significantly, whose potential hydroelectric power is approximately 50 per cent that of the whole United States.

Yet here is the odd situation. This great region, which uses twice as much power per person as the national average and which has all this hydroelectric power potential, is faced with an acute power shortage. How has it failed to meet the demands made upon its resources? What is being done to alleviate the situation, what is being planned, how is it to be accomplished and by whom? These are a few of the more important questions that must be answered, because the development of the Pacific Northwest is dependent upon having an abundance of hydroelectric power, and the economic welfare of the nation is coming, to an increasing extent, to depend on the development of the Northwest.

The history of commercial hydroelectric power in the Pacific Northwest began with an installation on a low-head waterfall in what is now the center of Spokane. This plant was built in 1887 and, together with its power distribution system serving the arc lights of the town, was the first commercial hydro-



BONNEVILLE DAM *Photo, Bonneville Power Administration*

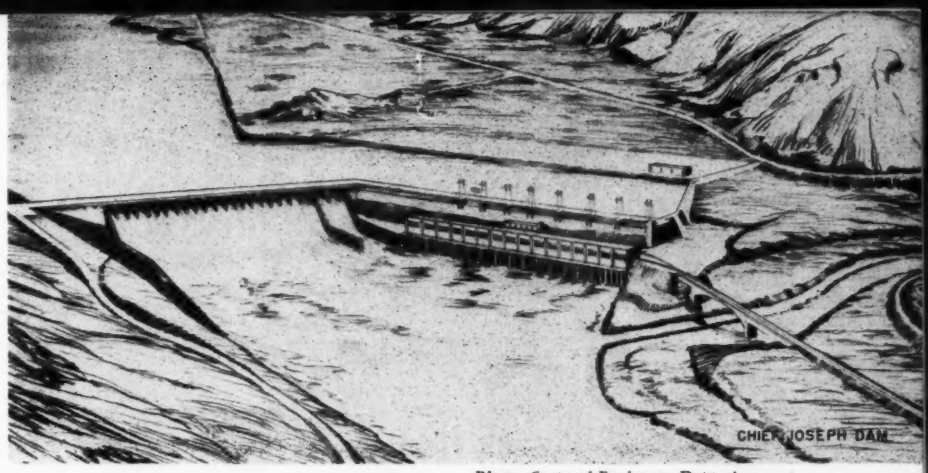
electric power enterprise in the Northwest and the beginning of the present extensive Washington Water Power Company network. The original 100-kw Edison bipolar generator has, unfortunately, been lost. A later plant constructed on the same site is still in operation. Other major accomplishments in the power system of the Northwest date from the completion of the Snoqualmie Falls plant in 1898, the development of the Skagit River project begun in 1907 by Seattle City Light, and the initiation of the Columbia Basin project in the 1930's.

The last project aroused considerable opposition from various groups of citizens and some congressmen who stressed the futility of building a power dam hundreds of miles from load centers, arguing that the land to be irrigated was worthless and that no market would exist for so much power. Fortunately, there were men with enough imagination to realize the vital importance of the projects and enough courage to keep on building in spite of opposition, with the result that Bonneville Dam on the lower Columbia was built, and Grand Coulee on the upper Columbia was begun.

During the 1930's private companies and the government expanded facilities in the Northwest at a sufficient rate to meet the current demand, but gave little consideration to future needs other than to allow for the normal expansion of cities and rural areas. A lingering impression of the Northwest as a "wilderness" still reflected to some degree the opinion of Daniel Webster who, a century ago, opposed acquisition of the Northwest Territory as a "vast worthless area, a region of savages and wild beasts—of shifting sands and whirlwinds of dust, of cactus and prairie dogs," and blinded public vision to the enormous value and endless possibilities of this undeveloped region.

By 1940, as armament preparedness began to take a larger share of the industrial output, and the United States sought to expand the plants producing critical war materials, increasing aluminum production was hampered in most parts of the country by the lack of an abundance of cheap power. In the Pacific Northwest, however, with the completion of Bonneville Dam and part of the Grand Coulee project, a cheap source of electrical energy became available for aluminum reduction. To bring this energy to the industrial centers, the government built a transmission line network to tie the generation plants to the load centers. In a further effort to meet the load requirements of the region, the major utilities and private companies tied their systems together for the interchange of power and in 1942 formed the Northwest Power Pool. Actually this interconnection had started on a small scale in 1924.

The Northwest Power Pool is a voluntary organization consisting of nine major utilities[1] and the Bonneville Power Administration. The purpose of the pool is to operate all power facilities as a unit



Photo, Corps of Engineers, Dept. Army

CHIEF JOSEPH DAM (Authorized)

to best serve the region and meet the total power demand during critical load periods. The various power systems are actually interconnected in a vast loop (see map), the backbone of which is the Federal Government 230-kv network of transmission lines and switching stations. The operation of the pool is accomplished by close cooperation of all the companies or utilities involved, and is coordinated by a committee composed of a representative from each member of the pool. The system hires an outside engineering firm for the detailed operation, but the over-all policy and business are handled cooperatively—an outstanding example of federal, private, and municipal cooperation.

Electrical energy is sold to the pool by the Bonneville Power Administration at a rate cheaper than it normally costs some agencies to generate their own power. The various members of the pool can either furnish or receive power from the pool, or, if their generating facilities are just sufficient for their own needs, they can remain connected to take advantage of available pool resources in case of emergency. Loads are carefully worked out and predicted with good accuracy from weather predictions, stream flow records, and previous experience with the industrial and residential loads. From the load predictions the agencies can tell whether they will have excess power, or whether they will need power, and the BPA can contract with pool members to supply certain amounts of power at specified times. Peak-load periods, fortunately, occur at different times in the region; for example, the peak-load period in the Butte, Montana, area occurs about an hour before the peak period on the coast. An additional diversification results from the fact that the various rivers in this region have widely divergent flow characteristics and reach their peak flows at different times of the year.

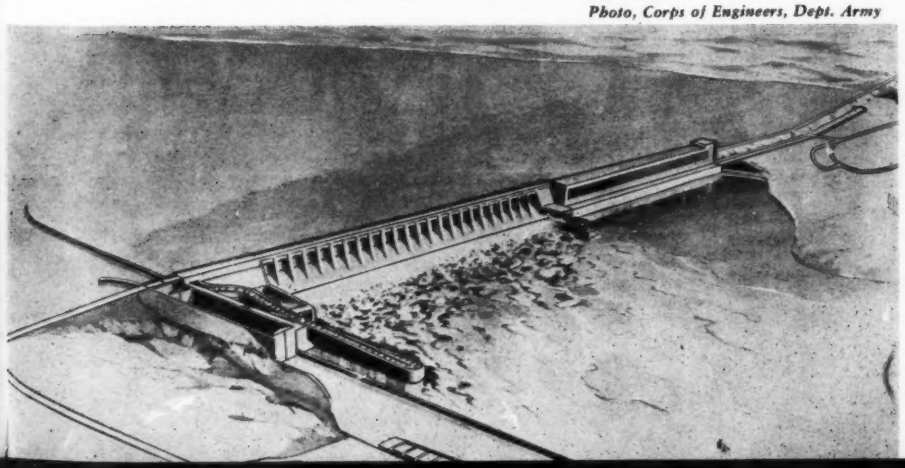
Thus it has been possible to add a certain amount of effective capacity to the pool without increasing the actual installed generating capacity. The interconnected system adds an "effective" capacity of 150,000 kw, and has increased operating facilities, decreased outages, improved maintenance schedules, and conserved vital supplies of fuel oil, an example of voluntary cooperation which enabled the Northwest during World War II to supply power to many vital war industries, including the Hanford Atomic Energy Project.

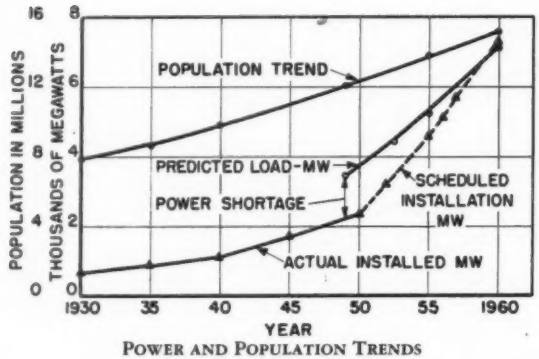
The Northwest Power Pool, which served so effectively during the war to alleviate the power shortage, has been continued because of the steadily increasing postwar power demand due to growing population, and additional heavy industries in the region. As an illustration, the population of Oregon and Washington increased more than 44 per cent in the period 1940-1948. Even with this population increase, the power consumption per capita in the Northwest is already more than twice the national average, and no decrease of the power demand is apparent. Predicted load curves,[2] based on estimated population curves (see graph), increase exponentially, making the demand for power increase more rapidly every year. The administrator of the BPA system has had to turn down many requests for power contracts simply because the system did not have the power to sell.[3] Other utilities in the region have had to reject possible industrial and heating loads for that reason.

The critical power shortage is well illustrated by the winter of 1948 when 3,800 megawatts supplied by the pool's generator capacity of 4,221.4 megawatts failed to meet the demands of the connected load

McNARY DAM (Under Construction)

Photo, Corps of Engineers, Dept. Army





POWER AND POPULATION TRENDS IN THE PACIFIC NORTHWEST

of the Northwest. Because the peak demand occurred during a period of low water, the rated output of the pool could not be produced. Although industrial loads were curtailed and residential consumers were requested to reduce the use of cooking equipment during peak hours, the pool's combined effort to maintain the normal 60 cycles failed, and the frequency sagged to 59 cycles. A study by the Electrical Engineering Department of the University of Washington, in collaboration with the agencies involved, indicates that the shortage of installed peaking capacity at the time of this 1948-49 power shortage was approximately 1,400 megawatts (1,400,000 kw). That is, the sum of the present connected load, the amount of load curtailed, the potential industrial load rejected, the natural increase incident to increased industry, plus a reasonable margin of reserve was greater than the actual installed capacity by 1,400,000 kw. Results of the research mentioned above have been presented in the writer's thesis.[3]

It becomes apparent, then, that the present power shortage is serious and may become critical. The question is: how can it be relieved? Private power companies have been reluctant to enter a large scale expansion program because of the possibility of condemnation and seizure of their holdings by public utility districts. For this reason, and because of other possible political complications, the private companies and the public utility districts have looked to the Federal Government to be the leader in this vast program of power expansion. In 1943 Congress empowered the Corps of Engineers of the United States Army to survey the Columbia River Basin and to make recommendations for its ultimate development. The report was completed in 1947 at a cost of over five million dollars, which seems excessively high until we remember that the Columbia River Basin drains an area of 259,000 square miles, extends north into Canada for 270 miles, south into the United States approximately 550 miles, and is 730 miles wide at the widest portion.

The entry of the Federal Government into power production was at first viewed with concern; but as the complexity of the situation became apparent, it was realized that no one private company would ever attempt a gigantic undertaking that would surely involve billions of dollars, and that was so vital to the conservation of natural resources and the security of the nation. On the basis of the Corps of Engineers' report (the "308" report), the President has approved and Congress is now considering a two-billion dollar appropriation designed to cover the development of hydroelectric plants and irrigation facilities in the Northwest.[4]

The Main Control Plan of the "308" report is concerned primarily with three phases of the development of the basin: flood control, improved navigation facilities, and power generation. Seven flood-control reservoirs are provided for: Grand Coulee, which is nearly completed, Hungry Horse, under construction (both Bureau of Reclamation projects), and Libby, Glacier View, Priest Rapids, Hells Canyon, and John Day, recommended for construction. (See map.) Included in the recommendations are also the following reservoirs that are planned mainly for local flood relief: Palisades on the Upper Snake; Anderson Ranch, Arrowrock, and Lucky Peak on the Boise River; Cascade and Garden Valley on the Payette River. All these reservoirs have an aggregate storage of about 4,100,000 acre-feet.

In general the seven reservoirs named will be used for flood control and power generation. Each unit has been designed to take care of the maximum flood recorded in its area, and there is also a master plan coordination between the dams to take care of the major floods on the Columbia and Snake Rivers. When the entire project is completed, Liberty ship traffic will be possible as far east as Lewiston, Idaho, and north to Wenatchee, Washington.

The power phase of the ultimate development of the Basin Project has been divided into five categories. They are identified as phases A, B, C-2, D, and E. Phase A includes the existing Federal projects on the Columbia; phase B includes the major projects authorized or under construction; phase C-2 adds all the flood-control projects; phases D and E are those projects tentatively proposed for later development.

Phase A includes Bonneville Dam with an installed capacity of 570 megawatts and Grand Coulee Dam with a present installed capacity of 1296 megawatts. Six more generators are scheduled to be installed at Grand Coulee in 1950 and 1951, making a completed capacity of 1,944 megawatts. At the end of 1951 the total capacity of Federal projects will be 2,462 megawatts. The total installed capacity for the pool at this time will be 5,635.2 megawatts, with a predicted

load demand of 6,000 to 8,000 megawatts.

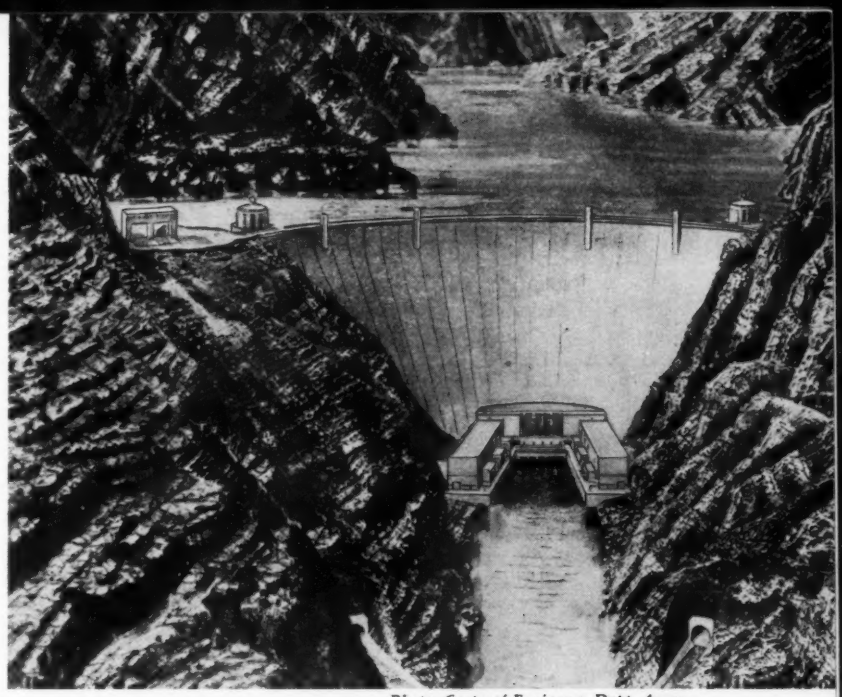
The projects in Phase B are scheduled for completion by the end of 1957 and include the following: Hungry Horse, 285 megawatts; Chief Joseph (Foster Creek), 640 megawatts; McNary, 980 megawatts; Lower Snake River Dams (4), a total of 1,000 megawatts. The total installed capacity of Federal projects at the end of 1957 will be 5,367 megawatts. The total installed capacity for the entire pool will be 11,804.8. Predicted load will be between 11,000 and 11,800 megawatts.

Included in Phase C-2 to be completed in 1960 will be the following projects: Glacier View, 210 megawatts; Libby, 588 megawatts; Priest Rapids, 1,219 megawatts; John Day, 1,105 megawatts, The Dalles, 980 megawatts; Hell's Canyon, 980 megawatts, and several smaller projects. The Federal System total by 1960 will be approximately 11,500 megawatts installed capacity.

These figures include the facilities of the nine major utilities previously listed. Several of these utilities are going ahead on expansion programs of their own. Seattle City Light is enlarging its Skagit Project, Tacoma City Light would like to start development of the Cowlitz River, but has been blocked by wildlife interests. The private companies in the Northwest are, for the most part, remaining inactive, uncertain of what their future will be.

One fact that is hard for the general public to realize is the time factor involved in building a dam and installing the generators. For example, Grand Coulee Dam was started in 1933, but the work of installing generators and the pumping plan is still not completed. Preceding the actual construction is a vast amount of engineering, office and field work. Therefore it is not unusual to hear power engineers talking about plans for ten years hence.

While the power situation is very acute at the present time, some relief will be afforded in 1953 when the first units of McNary Dam are scheduled to go on the line. Enough generators have been ordered to finish the Grand Coulee project, but these are the largest machines in the world and cannot be mass-produced. At the best, if the load follows the predicted curve, and we have every reason to believe that it will do so, the power shortage will not be over until 1958. In 1958 the basic required capacity to serve the predicted load will be 12,600 megawatts, and the scheduled capacity installed will be 12,911



Photo, Corps of Engineers, Dept. Army

HELLS CANYON DAM (Proposed)

megawatts. This leaves a small margin. In 1960 this basic required capacity will be 14,320 megawatts, and the scheduled installed capacity of 14,690 megawatts will provide a surplus of only 370 megawatts. This unsafe margin undoubtedly will be increased after 1960.

During the foregoing discussion the question of generation by steam-power plants has been purposely neglected. There is considerable question as to whether the hydroelectric or the steam-power method is more suitable, and less expensive in the long run. Hydroelectric power has the advantage of using a natural resource that is replenished every year; however, the cost of land condemnation and construction is high, and frequently the power must be transmitted over long distances. Steam plants can be designed economically to produce power for peaking and supplying some base load. At the present time two reports have been submitted to the Engineering Experiment Station entitled "Hydroelectric Power in Washington," and "The Economic Place of Steam-Power Generation in the Electrical System of Washington"* and are due for publication in the near future. Until the results are known from this research it is useless to make predictions or statements concerning the relative merits of the two methods of electrical power generation in the Pacific Northwest.

SUMMARY

A real and acute power shortage due to such factors as greatly increased population and industrial

(Continued on page 32)

*Engineering Experiment Station Project No. 84.

EDUCATING THE WHOLE MAN

STUART W. CHAPMAN
Director, Department of Humanistic-Social Studies
College of Engineering

S. W. Chapman

With the establishment of its program of humanistic-social studies in 1947, the College of Engineering of the University of Washington joined the ranks of engineering schools which have undertaken seriously the task of giving to their students an integrated, nontechnical education. Among engineering schools which are divisions of large universities, it is possibly unique in having its own department dedicated to the task of general education. It is certainly fortunate in being part of a university which has sanctioned such an educational venture.

The instructor of the humanities and social sciences in an engineering college must indeed have something of the spirit of the adventurer. The paths to his ultimate objective have been charted only in part and, even so far as they are known, may be difficult to follow. Previous experience with highly specialized study or with students whose primary interests lay in his own field constantly tempts him to take trails which are too frequently blind. And those who accompany him on his venture he finds neither are interested in making the trip nor have time enough to carry on until the goal is reached.

These problems are probably common to all general education; they are merely intensified in an engineering or other professional school. The student engineer usually gives his attention to nontechnical subjects grudgingly and of necessity. As a consequence the instructor learns to look upon a lively interest in the humanities and social studies on the part of his beginning students as a miracle, an attitude of neutrality as a blessing, and undisguised hostility as the normal expectation. Determination, vision, and a tough skin are vital qualifications for the teacher.

Were more time available, the problem of giving an effective general education would be simpler. But a professional school must think both of accreditation and of its primary job of giving a good technical training. Hence rarely can a student devote more than one-fifth of his time to nontechnical subjects, and within this allotment the instructor must work, though both he and members of the technical faculty may wish it could be greater.

Little wonder, then, that so many of the teachers of humanities and social studies in engineering schools need to be ardent apostles of their cause. In the face of special difficulties, they must have or acquire a firm conviction that their mission is worthwhile and that their problems are not so much insuperable obstacles as challenges to achievement.

Those who accept the challenge certainly have the facts on their side. In these days of necessary specialization, widespread group activity, and increased leisure, the humanities and social studies have much to give to the professional training of the engineer. Three major types of contribution are readily apparent. The humanistic-social studies can strengthen the student's skill in good methods of thinking, can help him to work and live better as a man in a democratic society, and can enlarge the resources he possesses as an individual who has to live not only with others but also with himself.

The first of these areas is the one in which technical and nontechnical education can most readily be integrated and where the professional character of humanistic-social education is most easily seen. The reason is simply that good thinking is good thinking in whatever field it is used; that the fundamental process of solving a problem is the same whether it involves the production of a play, the answering of a question in history, or the designing of a machine; that the development of the skill of thinking well in any field can intensify the same skill in another. No profession, no study, no one group of individuals has a monopoly on good thinking. The engineering student should realize this. Likewise he should recognize that learning to think well in one line of work, while it does not guarantee like skill in every other situation, can contribute to it.

Every one of the humanities or social studies can be used to illustrate good methods of thinking and of problem-solving. Economic analysis, whatever its

shortcomings at present, must certainly be carried out with due regard for available facts as well as for generalizations. History is full of problems which can be answered only if valid evidence is accumulated and logical conclusions are drawn from that evidence. In psychology the student can be trained to look for all the significant factors in a situation and to take action only after relevant information is available. Even in a work of art the student can be shown how the real artist, trying to communicate an idea, an attitude, or a mood, must analyze his problem, determine what forms, techniques, colors, words, or harmonies will achieve his purpose, and then fit them together into a great picture, literary work, or piece of music.

Especially effective work can also be done in illustrating the important part played by judgment in those situations where the facts necessary to a completely valid conclusion are not all available. From his technical work the student, particularly in his early years, often gets the impression that a single correct answer exists for every problem. He expects to find this answer and thinks that something is wrong when a cut-and-dried solution is not forthcoming. No better antidote for this undesirable attitude exists than the social sciences and the arts. Through them the student can be confronted time and again with problems whose answers depend upon the exercise of good judgment. Consider a discussion of and decision regarding the desirability of a Columbia Valley Authority. This problem involves applications of social ideals, technical elements, and economic and political knowledge so extensive that no engineering student could hope to obtain or to master all of the evidence necessary to a completely valid decision. This is particularly true since the problem involves predictions of future events. Yet this question must be decided and the conclusion must be reached by an exercise of judgment, good or bad. No student who is constantly confronted with such questions can be totally surprised if some day his professional work lays such a problem in his lap; nor should he be completely unprepared to cope with it.

Beyond any doubt the teaching of good methods of thinking is essential in a democracy; but logical thought is not enough, since so much depends upon the original assumptions upon which logic is based. Good citizenship entails understanding and good will; understanding and good will entail knowledge and a keen sense of values. Both of these the humanities and social sciences can help the engineering student to acquire.

Hence the humanistic-social studies must achieve some success in helping the student (1) to gain a set of values and attitudes which will serve him in a rapidly changing world, (2) to learn the nature of the problems which confront modern civilization, and (3) to discover the nature of man and the motives which energize him. Available for these tasks is a veritable treasury. From philosophy, religion, history, anthropology, literature, and the arts (to specify some of the sources), come expressions of all types of values as well as illustrations of the implications of those values when they are applied to life. No student who ponders these subjects even briefly can avoid questioning at least once the relevancy and adequacy of some of the standards by which he guides his life.

As for the understanding of modern problems and the men who make and must solve them, these are in the very vitals of the humanities and social studies. It is not merely that psychology elucidates man's reactions and motivations, individually and in groups, nor that history clarifies our present position by telling us something of how we came to be here. Anthropology, economics, sociology, these also have produced concepts and principles which illuminate our problems and could help us to an amelioration of them if but sufficient people knew and believed. And where can we go to find more penetrating analyses of man and society, clearer understanding of what makes people tick, more vivid portrayals of ideals than are to be found in great literature, art, religion and philosophy, both past and present?

It follows as day the night that those students who learn to think well, to comprehend more fully the world and its people, and to develop a sense of values will, in the vast majority, become real adults, knowledgeable, understanding, confident but not proud, and possessed of inner resources which will make life always interesting, meaningful, and challenging. They will become more complete men and women and thus better people whether at home or in industry, in private practice or in public life, leading or following, solitary or joined with others in common enterprise.

Education of this type is neither easy to give nor easy to absorb, especially when those who are learning often have so little stomach for the enterprise at the beginning and so little time to digest it before its close. Inherent in this situation are certain implications.

The first of these is that whatever is taught of the humanities and social studies must be fundamental. After his exposure to nontechnical subjects, the student must find burned into the very flesh and blood of his thinking some of the most important concepts and principles suggested by scholars in those fields. Fact, as facts to be memorized and echoed back, are unimportant; facts as evidence pointing to suggestive principles are imperative. The instructor cannot expect that the student, in a few hours out of his lifetime, can learn everything, or can even learn to love all that the teacher himself finds exciting. Since time

in humanistic-social curricula is seldom either continuous or adequate, the student has received less than he deserves if he emerges without an understanding of basic generalizations which have risen out of the fields he has studied.

This leads to the second implication inherent in the situation confronting teachers of nontechnical subjects: what the student learns must be useful. Now utility may be measured in different ways. One of these is, of course, usefulness in getting, keeping, and improving the student's job. Although this is often the sole criterion for the embryonic engineer, for the educator it should be only one of several standards. Certainly he should not blush with shame if he helps make his students better workers, but he should be disturbed if he does nothing more. To the degree that nontechnical subjects are taught merely with the job in mind, to that degree they are more technical and less liberalizing. Making a subject relevant to the job is both a device for arousing interest and a worthy objective, but it should never be the exclusive goal.

Since life cannot be measured solely in hourly wage rates, the humanities and social studies can be useful in ways not directly connected with the job. The student will find any idea useful so long as it makes him feel that he has gained a better adjustment to or greater influence over his environment. Thus if he learns enough about modern painting to begin to enjoy it, that understanding is useful to him, far more so than a memorizing of a series of treaties, or even of some technical material for which he can see no application. But if the treaties he has memorized have given a better understanding of contemporary international conflicts, then they may be more useful to him than all his labor in literature and the arts, if it has brought him neither appreciation nor understanding. The instructor of the humanities and social studies needs constantly to ask himself this question: "Is this that I am teaching necessary and useful mainly to the scholar and specialist, or can it be taken by an engineering student and made useful at once as a means of understanding himself and his fellow man, of appreciating his own profession, of broadening and intensifying his pleasures, of making his associations more satisfying?" If the teacher can succeed in making most of what he teaches immediately useful, he need worry little about exciting his student's interest.

The last implication of the situation in engineering schools is that students must do in their humanistic-social courses what they are being prepared to do in later life. True, a man learns by listening, but only if he himself does something, cerebral or muscular, as a consequence. If we want engineering students to become storehouses of facts and formulae, then we should drill, drill, drill, and quiz, quiz, quiz, until we are satisfied that the facts and formulae have been driven home and clinched. If, however, we wish to turn out students who are capable of thinking methodically and well when confronted with new problems, then we must confront them with new problems and then encourage and help them toward solutions. If we want to raise their potential of creativity, then we must assist them in creating something; if we desire to quicken a sense of values, then we must put the student in situations where he is forced to evaluate and see the consequences of the standards which he adopts. In no other way can he learn so quickly, so thoroughly, and so lastingly as by doing himself.

Would that our Humanistic-Social Department could claim to have accomplished all this! But important steps have been taken. For one thing, a staff of eleven people has been assembled. Subjects of specialized study and experience represented by this group include English, music, drama, history, the classics, anthropology, and engineering. Practically all of the staff have advanced degrees, some have the doctorate, and others are in process of obtaining it. While none is inclined to doubt the value of advanced study, all are primarily interested in the job of teaching and are genuinely interested in the specific problem of teaching engineering students.

Assisted by an Advisory Committee composed of two members of the engineering faculty and three from the College of Arts and Sciences, the department functions as one of the units of the College of Engineering. It has quarters of its own on the second floor of Engineering Hall. Here is located also one of its main educational resources, a library of books in all major fields plus many current periodicals. Audio-visual equipment at present consists of two slide and film-strip projectors, 16 mm. sound movie projector, tape recorder, record player, and collections of slides and records.

With a capable faculty and much good physical equipment in its possession the department is well prepared for its work. The program is ambitious, but naturally three years of experience with it has not been enough to bring us even close to our objectives. In the sixteen quarter-hours of the complete curriculum we strive to give training in report-writing; to instruct in methods of problem-solving; to make the student aware of the nature and pitfalls of the language he uses; to give him experience and direction in writing and practice in speaking; to acquaint him with basic biological concepts and with some of the anthropologist's views about the nature of culture; to give him greater understanding of the background of his own culture; to stimulate his interest in and analysis of contemporary social problems; to sharpen his sense of values through contact with some of the

great philosophies and religions; to help him find and leave more of beauty in life through appreciation and understanding of the arts. And we try to encourage students to read, hoping that through books they may find an avenue to lasting growth.

This is much to attempt. It probably can never be done to the degree we should like, even if some day we are able to continue our work with students who are doing graduate work in engineering. Meanwhile our intent is to review our goals, our curriculum, and our teaching methods periodically, in the full expectation that through self-evaluation, coupled with criticism and suggestions from students, alumni, technical faculty, and any others interested in our program, we shall be able gradually to eliminate dead wood, repair omissions, clarify our purposes, and sharpen our teaching methods. This much we owe to ourselves and to the students whom we are trying to help to become better workers, better citizens, and more complete men and women.

LATERAL BUCKLING OF SIMPLY-SUPPORTED I-BEAMS*

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N. C. Cyr

Introduction

Eighteen tests of 7"x2-1/8"x5.5# Jr. beam sections were made as a step toward verification of a new formula for the lateral buckling of rolled steel wide-flange beams and I-beams. This formula was developed by K. de Vries[1] and includes the effect of the beam depth and the thickness of the flange in a new ratio, ld/bt, instead of expressing the critical compressive stress in the compression flange as a function of the l/b ratio. In this slenderness ratio, l is the unsupported length of the compression flange, d is the depth of the beam, b is the width of the flange, and t is the average thickness of the flange. This formula assumes a simply-supported straight beam with a constant moment of inertia and with the top flange restrained in the lateral direction at the supports by a pin.

The program of the tests is given in Table I and includes simply-supported beams with, and without top-flange restraint. In all the tests equal loads were applied at the two quarter-points of the beam.

The torsion test was made in a manner which left the ends of the beam free to warp.

All of the test specimens were cut from two beams. Two tensile specimens were cut from the flanges of each of the two beams to determine the mechanical properties listed in the following table, where each value is the average of two tests:

R. A. Hechtman

Beam	*Upper Yield Point psi*	*Lower Yield Point psi*	*Modulus of Elasticity psi*	*Torsional Constant T/θ lb-in.*
A	42,450	38,600	29,700,000	260,000
B	41,600	38,500	28,400,000	

In Fig. 1 the method of loading is shown. The bridles which applied the load to the beam were pinned at the four corners and the extension rods were pinned to the bridles and to the loading beam. The advantage of this method was that it offered no lateral restraint against the top flange which could prevent buckling .The manner in which the top flange was restrained at the supports allowed the beam to rotate in the horizontal plane, but prevented lateral movement of the top flange. For the tests without top-flange lateral restraint, the same test set-up was used, except that the top flange of the beam was entirely free to move laterally.

* The material for this report was taken from the thesis of N. C. Cyr in partial fulfillment of the requirements for the degree of M.S. in C.E. Dr. R. A. Hechtman supervised the work, which was done in the Structural Research Laboratory of the Department of Civil Engineering.

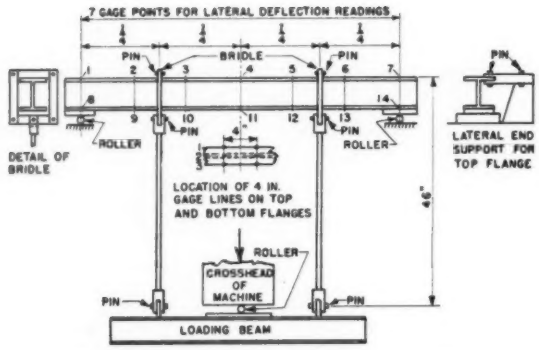


FIG. 1. METHOD OF LOADING AND LOCATION OF GAGE POINTS

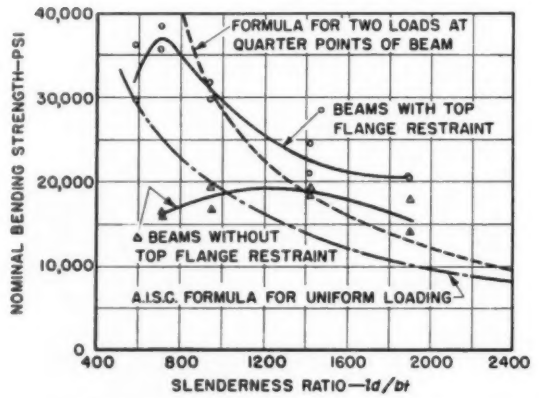


FIG. 2. NOMINAL BENDING STRENGTH AT CRITICAL LOAD FOR 7" x 2⅛" x 5.5# JR. BEAMS WITH VARIOUS *ld/bt* RATIOS AND DIFFERENT TYPES OF END SUPPORT

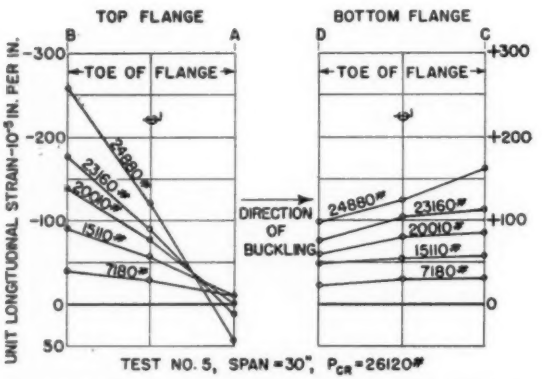


FIG. 3. UNIT LONGITUDINAL STRAIN DISTRIBUTION AT MIDSPAN ON 4-IN. GAGE LENGTHS ON BEAM FLANGES

Data of Tests

Nominal Bending Strength for Various ld/bt Ratios. A comparison of the nominal bending strength and the slenderness ratio, *ld/bt*, is plotted in Fig. 2 for all of the tests. These data are also given in Tables II and III. The curves for two theoretical formulas are also plotted in Fig. 2, the A.I.S.C. formula for uniform loading and a formula for a simply-supported beam with equal loads at the two quarter-points and top-flange lateral restraint. The formula for the latter plot was derived by Kuo Tsun Chang,[2] research fellow in the Engineering Experiment Station, who employed the method set forth by de Vries.

The nominal bending strengths of the beams with top-flange restraint fell above both the A.I.S.C. formula and the curve for two-point loading for *ld/bt* ratios greater than 950. The nominal bending strengths of the beams with *ld/bt* ratios smaller than 950 fell below the curve for two-point loading, but were still above the A.I.S.C. formula for uniform load. In the 30-inch beams, web crippling preceded lateral buckling and reduced their nominal bending strength.

Beams without top-flange restraint and with *ld/bt* ratios between 1,400 and 1,900 failed at about 70 per cent of the nominal bending strength of the beams without top-flange restraint. As the *ld/bt* ratios of the beams decreased from 1,400 to 700, the nominal bending strength remained almost constant.

Lateral Deflections of Beams of Various Lengths. The lateral deflections at the midspan of the top and bottom flanges of the various beams with top-flange restraint are given in Table IV, and for the beams without top-flange restraint in Table V. These values were measured at, or near the buckling load. The lateral deflection of the top flange was greater than the lateral deflection of the bottom flange for all of the tests except Tests No. 2 and No. 8. The top flanges of the beams without top-flange restraint had larger lateral deflections at midspan than those beams of the same length with top-flange restraint.

Lateral deflection of the top flange at the support points occurred for the initial load in almost every test of the beams without top-flange restraint and increased until failure by lateral buckling occurred. In all of these tests the entire width of the bottom flange at the supports remained in contact with the support rollers, even after buckling occurred.

Unit Strains in the Flanges of the Beams. The longitudinal strain distribution across the beam flanges at midspan is shown at various loads for a typical test in Fig. 3. As the combined effect of bending in two planes and torsional warping of the cross sections increased, the distribution of the longitudinal strain became increasingly nonuniform. Table VI

TABLE I

PROGRAM OF TESTS

Simply-Supported Beams with Top-Flange Lateral Restraint at the Supports

Test No.	Span Inches	*ld/bt* Ratio	Beam from which Specimen Cut
9	96	1,900	A
10	96	1,900	A
1	72	1,420	B
4	72	1,420	B
6	48	949	B
7	48	949	B
3	36	711	B
8	36	711	B
2	30	592	B
5	30	592	B

Simply-Supported Beams without Top-Flange Lateral Restraint at the Supports

Test No.	Span Inches	*ld/bt* Ratio	Beam from which Specimen Cut
11	96	1,900	A
12	96	1,900	A
13	72	1,420	A
14	72	1,420	A
15	48	949	A
16	48	949	A
17	36	711	A
18	36	711	A

TABLE II

NOMINAL BENDING STRENGTH OF BEAMS WITH TOP-FLANGE LATERAL RESTRAINT

Test No.	Span Inches	*ld/bt* Ratio	Critical Load-Lb	Nominal Bending Strength-psi
9	96	1,900	5,680	20,500
10	96	1,900	5,580	20,200
1	72	1,420	9,000	24,400
4	72	1,420	7,680	20,800
6	48	949	17,500	31,600
7	48	949	16,310	29,500
3	36	711	26,100	35,400
8	36	711	28,120	38,100
2	30	592	31,930	36,000
5	30	592	26,120	29,500

TABLE III

NOMINAL BENDING STRENGTH OF BEAMS WITHOUT TOP-FLANGE LATERAL RESTRAINT

Test No.	Span Inches	*ld/bt* Ratio	Critical Load-Lb	Nominal Bending Strength-psi
11	96	1,900	3,790	13,700
12	96	1,900	4,855	17,500
13	72	1,420	7,085	19,200
14	72	1,420	6,790	18,400
15	48	949	10,610	19,200
16	48	949	9,160	16,550
17	36	711	12,110	16,450
18	36	711	11,920	16,200

TABLE IV

LATERAL DEFLECTIONS AT MIDSPAN OF BEAMS WITH TOP-FLANGE RESTRAINT

Test No.	Span In.	Load at Reading—Lb	Lateral Deflection—1/1000 In.	
			Top Flange	Bottom Flange
9	96	5,160	167	47
10	96	5,190	182	74
1	72	9,000*	230	55
4	72	6,230	230	66
6	48	17,270	162	26
7	48	16,020	152	25
3	36	25,030	44	11
8	36	25,300	29	34
2	30	30,000	62	16
5	30	24,880	160	18

*Buckling load.

TABLE V

LATERAL DEFLECTIONS AT MIDSPAN OF BEAMS WITHOUT TOP-FLANGE RESTRAINT

Test No.	Span In.	Load at Reading Lb	Lateral Deflection—1/1000 Inches			
			Top Flange			Bottom Flange Midspan
			North Support	Midspan	South Support	
11	96	3,700	109	515	105	194
12	96	4,535	36	157	5	44
13	72	7,085*	60	271	82	72
14	72	6,570	121	358	152	112
15	48	8,330	90	128	133	11
16	48	8,280	160	225	137	30
17	36	11,840	358	324	165	43
18	36	11,600	329	317	177	42

*Buckling load.

TABLE VI

UNIT STRAINS ON TOES OF BEAM FLANGE AT MIDSPAN

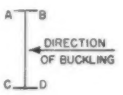
Load at, or Near, Critical Load

Simply-Supported Beams with Top-Flange Lateral Restraint at the Supports

Test No.	Span In.	Unit Strain—1/10,000 In. per In.				
		Load at Reading Lb	Top Flange		Bottom Flange	
			A	B	C	D
9	96	5,160	−5	−7	+5	+4
10	96	5,190	−4	−8	+8	+5
1	72	9,000	−4	−15	+7	+6
4	72	6,230	0	−10	+7	+5
6	48	17,270	−4	−18	+18	+9
7	48	16,020	−5	−17	+16	+10
3	36	25,030	−9	−15	+13	+15
8	36	25,300	−11	−15	+23	+11
2	30	30,000	−5	−18	+13	+11
5	30	24,880	+4	−26	+16	+10

Simply-Supported Beams without Top-Flange Lateral Restraint at the Supports

Test No.	Span In.	Unit Strain—1/10,000 In. per In.				
		Load at Reading Lb	Top Flange		Bottom Flange	
			A	B	C	D
11	96	3,700	−1	−9	+5	0
12	96	4,535	−4	−7	+5	+4
13	72	7,085	−2	−11	+8	+3
14	72	6,570	−2	−9	+7	+5
15	48	8,330	−5	−6	+3	+4
16	48	8,280	−2	−9	+7	+3
17	36	11,840	−2	−9	+9	+2
18	36	11,600	−1	−8	+10	+5



gives the values of the unit longitudinal strains on the toes of the flanges of the beams at midspan for loads very near to, or at the critical load. Examination of the data in this table indicates that the maximum compression strain in the compression flange of the beams was in the neighborhood of the yield point strain of the steel when lateral buckling occurred.

Effect of Initial Eccentricity upon the Buckling Direction. The initial eccentricities of the beams were measured before testing. Nine beams buckled in a direction opposite to the initial eccentricity, while six beams buckled in the same direction as the initial eccentricity. The initial eccentricities of two beams were not measured, and one beam was straight.

Discussion of Test Results

Figure 2 presents a comparison of the nominal bending strength with the A.I.S.C. formula for uniform load and the curve for two-point loading. The nominal bending strengths of the beams with top-flange lateral restraint fell above both the theoretical curve for two-point loading and the A.I.S.C. formula for ld/bt ratios greater than 1,400 and below the curve for two-point loading for the shorter beams. Some explanation for this kind of behavior can be found in a study of the unit strain distribution across the top flange at midspan of the beams. This yielding was greater in the 36-inch and the 48-inch beams than in the longer beams. The yielding that occurred before the critical load was reached caused the nominal bending strength of the beams with top-flange restraint to increase less rapidly than theory would predict as the slenderness ratio of the beams was decreased. Where yielding took place before lateral buckling occurred, as it did in all beams with top-flange restraint with ld/bt ratios less than 1,900, the yield point of the steel as well as the modulus of elasticity was necessary to define the buckling strength of the beams.

Beams without top-flange lateral restraint had lower buckling strengths than those with top-flange restraint for all the lengths tested. Since the top flanges of the beams without top-flange restraint were free to move laterally at the support points, the end restraint against torsion was supplied only by the bearing of the bottom flange on the support. The behavior of the beams with ld/bt ratios less than 1,400 indicated that the slenderness of the web in the vertical plane probably had a more significant effect upon their load-carrying capacity than the longitudinal slenderness of the beam.

SUMMARY

The investigation reported herein had as its purpose the comparison of the values of the nominal bending strength predicted by theoretical analyses with those values determined experimentally. The yielding in the compression flange of the 7-in. Jr. beams with ld/bt ratios between 600 and 1,900 significantly reduced their resistance against lateral buckling. This yielding was due to the combined effects of bending in both the vertical and horizontal planes and to the torsional warping of the cross sections of the beam. The results of this program indicated that the yield point of the steel as well as the modulus of elasticity was necessary to define the buckling strength of the I-beams in this range of the slenderness ratio.

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SEPARATION OF AMINO ACIDS BY ION EXCHANGE*

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The writers wish to record some preliminary work directed toward separation of mixtures of amino acids in aqueous solution by procedures involving use of ion exchange resins.

This separation problem is of interest immediately for many theoretical reasons and also from a longer range point of view, because mixtures of amino acids in aqueous solution could readily be prepared on an industrial scale by hydrolysis of protein material contained in fish waste or in wheat. Large amounts of fish wastes are available or potentially available at various points in the states of Washington and Oregon, and these quantities as estimated by Butler[1] for the year of 1943 are summarized in Table I. In Alaska there may be discarded an additional 50,000,000 to 100,000,000 pounds of fish material. This fish waste is found at various levels of availability and some is now being utilized for production of oil and meal. However it appears that adequate scope exists for further development of uses for this material. Protein in industrial quantities would also be available from wheat if starch and syrup production from this grain were undertaken in the Pacific Northwest.[2]

Individual pure amino acids are being used increasingly for medical or special dietary purposes and, sometime in the future, pure amino acids may conceivably assume a place of importance in the ordinary diet of man. The nature and proportion of amino acids which make up many proteins have been extensively investigated, although in many cases only incomplete results are as yet at hand because some amino acid destruction may occur during protein hydrolysis and also because quantitative analysis for individual amino acids is often difficult. Summarized data of this kind* for tissues of various fish show, for example, the presence in codfish muscle tissue of some twenty amino acids in amounts ranging up to some 8.6 per cent for lysine as reported by one investigator[3] or 11.55 per cent by another.[4]

J. L. McCarthy

The present production of certain amino acids is conducted more or less simply by the methods of synthetic organic chemistry. For others, moderately easy specific procedures are available for laboratory separation from protein hydrolyzate mixtures and at least one amino acid, glutamic acid, is understood now to be produced by separation from hydrolysis products of gluten.

Generally applicable separation procedures for small amounts of amino acids are now being developed. The technique of partition chromatography was used in 1949 by Moore and Stein[5] of the Rockefeller Institute for Medical Research to separate a mixture of eighteen different amino acids, in most cases into substantially pure substances. For this work, a binary solvent system consisting of *n*-butanol and water was employed on a column of starch granules as the supporting medium.

A. E. Markham

Differences in partition

* Extracted from theses submitted in partial fulfillment of the degree of M.S. in Ch.E. by Z. E. Carey ("Ion Exchange Separation of Amino Acids," 1949) and R. D. Toomey ("The Dialysis of Acid-Hydrolized Salmon Protein," 1946).

* R. D. Toomey, Thesis, Table I.

coefficients of the several amino acids between the mobile butanol phase and the immobile water-starch phase provided the basis for this multistage separation process. On their column, which was about 9 mm in diameter and 300 mm in height, the total amino acid loading was about 2 to 3 milligrams, and it is improbable that this could be greatly increased without rather seriously interfering with the successful execution of the separation process. Thus while the column of Moore and Stein operated with many theoretical transfer units, yet the partition chromatography procedure seems to suffer from the shortcoming of low capacity because (a) amino acids are only limitedly soluble in the moving organic solvent phase, and (b) the amounts of water held immobile on the starch are small.

An alternative way to separate ionically dispersed substances is by ion exchange chromatography which has been used for separation of cationic substances resulting from nuclear fission.[6] Amino acid separations by this method have also been investigated and have been reviewed by Block.[7] Since amino acids are extensively soluble in the mobile aqueous phase, and since ion exchange resins are now available with relatively large capacity, it seemed possible that ion exchange chromatography might permit separations to be effected on a somewhat larger scale than appears to be feasible with partition chromatography. Thus this preliminary study of the ability of ion exchange resins for chromatographic separation of amino acids was carried out to detect the factors which might later be of importance in larger scale experimentation.

Experimental Procedures

Materials

The amino acids for this investigation, l(+) arginine, (obtained as the hydrochloride), l(—) cystine, and l(+) glutamic acid were obtained from the Eastman Kodak Company and were used without further purification. The cystine and glutamic acid were dissolved in hydrochloric acid.

The resin used was Dowex-50, supplied to us through the courtesy of the Dow Chemical Company. The resin particles passing a 20-mesh, and retained on a 35-mesh screen (about 30 per cent of the total), were used in the experiments. To free the resin from extraneous ions, it was washed alternately with 2.0 normal hydrochloric acid and 5 per cent sodium chloride solution, and finally with the acid to leave the resin in the hydrogen base form. The resin was kept in air-dry condition. Analyses showed it to contain 0.128 per cent of ash, based on oven-dried resin. The capacity of the resin, determined by the procedure of Bauman and Eichhorn,[8] was 4.93 milliequivalents of exchangeable ion per gram of oven-dried resin.

Equilibrium Experiments

Equilibrium experiments were carried out in 250-ml glass-stoppered bottles, to each of which was added 0.5000 g of air-dried resin, and 100 ml of amino acid solution containing from 0.5 to 2.0 millimoles of amino acid. One ml of toluene was added to each bottle to inhibit the growth of microorganisms. The bottles were sealed and rotated slowly in a water bath at 25.0° C for 24 hours. They were then opened, the solution separated from the resin, and the pH and amino acid concentration of the solution determined.

Column Experiments

For these experiments vertical glass tubes of 13 mm i.d. were filled with resin to the desired heights. Fresh resin was used for each experiment. Height of the resin column was determined after water had flowed through the column until a constant height was reached.

The amino acids were dissolved in hydrochloric acid solution at pH 1.5. Fifty milligrams of each amino acid was dissolved in 500 ml of solution. This solution was passed through the resin column at a rate of 40 ml per hour and then 200 ml of water was flowed in order to rinse the column. Elution was carried out using hydrochloric acid solutions which were fed to the column from an inverted flask which maintained a constant liquid head. The solution flowed through a capillary tube which controlled the flow rate. The combination of constant head and capillary restriction maintained a constant rate of liquid flow. An automatic sampling device changed the receptacles for the column effluent at appropriate time intervals, and these effluent samples were later analyzed.

Analytical Methods

Glutamic Acid: The ninhydrin procedure described by Snell[9] was used for the equilibrium study. This procedure is not applicable to mixtures of amino acids, and in column experiments the method of Danielson[10] was employed to give total amino acid nitrogen. Arginine and cystine were subtracted to determine glutamic acid.

Cystine: For determination of 0.05 to 0.4 mg of cystine, the method of Hunter and Eagles[11] was used, with some modifications, while for amounts of 0.5 to 5.0 mg the method of Morenzi and Folin[12] served.

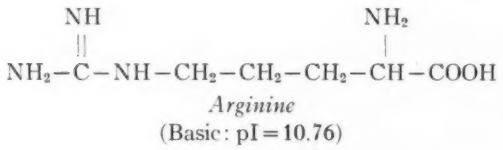
Arginine: The method of Macpherson[13] was used for amounts of 0.04 to 0.4 mg of arginine, and that of Jorpes[14] for amounts of 0.015 to 0.035 mg.

Traces of amino acids were determined by the ninhydrin procedure of Harding.[15]

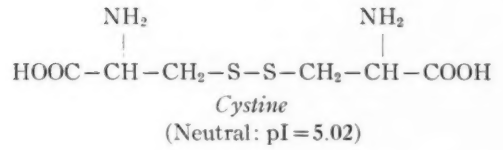
Discussion

The present investigation was conducted with known mixtures of pure amino acids because of the greater ease in interpretation of results as compared with protein hydrolyzates. Some earlier studies on acidic hydrolysis of salmon tissue were carried out along with determination of dialysis rate constants on the hydrolyzate substances. It is hoped that separation experiments can later be extended to protein hydrolyzates.

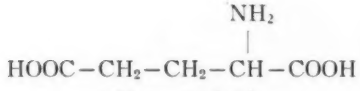
The three amino acids chosen for study were arginine, cystine, and glutamic acids, both because they are components of fish protein and because of their widely different isoelectric points which reflect the basic, acidic, and neutral character of the substances.



Arginine
(Basic: pI = 10.76)



Cystine
(Neutral: pI = 5.02)



Glutamic Acid
(Acidic: pI = 3.08)

TABLE I

Fish Waste Available in Washington and Oregon Areas (Estimated by Butler[1])

Area	*Waste Potentially Available in 1943 (lb)*
Seattle, Wash.	13,127,266
Grays Harbor, Wash.	3,511,690
Astoria, Oregon	33,140,000

TABLE II

Values of Parameters in Equilibrium Isotherms of Glutamic Acid, Cystine, and Arginine between Dowex 50 and Aqueous Phase

Amino Acid	*K*		*p*	
	Present Expts.	*Cannan*[17]	*Present Expts.*	*Cannan*[17]
Arginine	2.95	6.0	0.21	0.75
Cystine	1.58	....	0.33	.....
Glutamic Acid	0.03	0.4	1.42	1.10

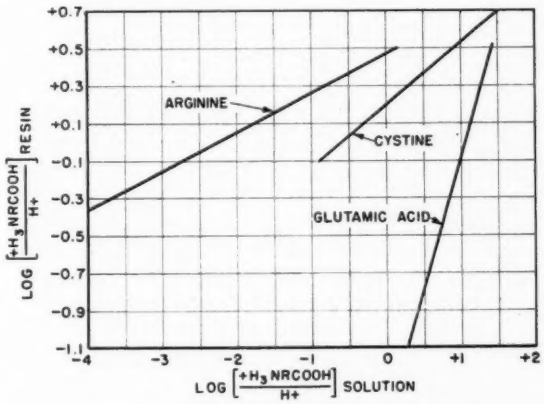


FIG. 1. EQUILIBRIUM OF SEVERAL AMINO ACIDS ON DOWEX 50

TABLE III

Summary of Column Separation Results

Expt.[a]	OPERATING CONDITIONS		GLUTAMIC ACID					CYSTINE					ARGININE				
	Flow ml–cm² hr	Eluant N HCL	Max. Conc. mg/l	Recov.[b] %	C[c]	p[d]	Ht/p[e] cm	Max. Conc. mg/l	Recov.[b] %	C[c]	p[d]	Ht/p[e] cm	Max. Conc. mg/l	Recov.[b] %	C[c]	p[d]	Ht/p[e] cm
3	28	2	730	81	1.2	9	5.3	135	98	8.2	9	5.3	55	100	40	31	1.5
4	100	2	380	98	1.1	2	25	90	104	6.1	2	21	30	103	50	14	3.4
5	37	4	1230	107	1.1	20	2.4	350	88	2.2	5	9	150	86	6	6	8
6	32	1	460	100	2.2	9	5.3	50	84	41	26	1.8	21	95	230	144	0.3
7	37	2	420	70	1.6	18	5.3	52	90	8	5	19	24	98	32	15	6.4
8	32	2	920	94	2.8	14	1.7	175	101	12	7	3.4	59	90	46	11	2.2

[a] For Experiments 3, 4, 5, and 6, Column Height = 47.5 cm and V = 0.050 liter; for Experiment 7, Column Height was 95 cm and V = 0.100 liter; for Experiment 8, Column Height was 24 cm and V = 0.025 liter.

[b] % of 50 mg put on the column.

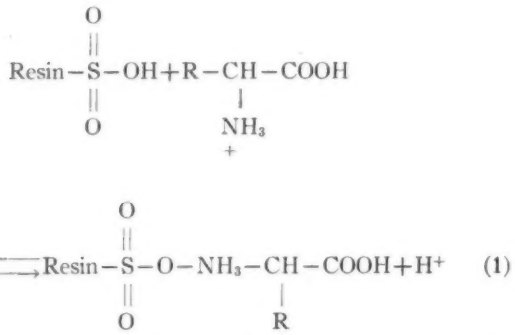
[c] C is a function of the partition coefficient as defined in the text.

[d] p is number of plates as calculated by Mayer and Tompkins treatment.

[e] Ht/p is the height of resin column per plate.

Equilibrium partition and column separation experiments with these three amino acids were conducted using the cation exchange resin, Dowex 50, a sulfonated polystyrene described by Bauman.[8]

Reaction between this resin and a simple amino acid apparently proceeds as follows:



$$\rightleftharpoons \text{Resin}-\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}-O-NH_3-\underset{\underset{R}{|}}{CH}-COOH+H^+ \qquad (1)$$

Rothmund and Kornfeld[16] have proposed that the expression for an equilibrium constant, K'_c be modified by introduction of an empirical constant p which can be determined from a logarithmic plot of equilibrium data based on the equation:

$$\log\left(\frac{C_{AR}}{C_{HR}}\right)=\log K'_c+p\log\left(\frac{C_{AS}}{C_{HS}}\right) \qquad (2)$$

where C represents concentration of amino acid or hydrogen in millimoles per milliliter of solution, or per gram of air-dry resin; the subscripts A and H represent amino acid and hydrogen, respectively; and the subscripts S and R represent solution and resin, respectively.

In present equilibrium experiments with the three amino acids, it is found that the data plotted in accordance with the above equation yield to an approximately linear representation as shown in Fig. 1 in spite of the questionable univalent relationships. Values of K'_c and p calculated from these data are shown in Table II along with the results reported by Cannan[17] for two amino acids, using a different resin.

For separation studies, known mixtures of the three amino acids were absorbed on resin columns and then eluted with hydrochloric acid solutions at various conditions of column height, flow rate, and concentration of hydrochloric acid. (See Table III.) Eluants were collected incrementally and analyzed.

Graphical representation of these elution data in Fig. 2 shows qualitatively the extent of separation of the different amino acids and, in some cases, this is quite satisfactory. Amino acid recovery was usually close to complete. Quantitative treatment of the elution data is possible by the use of the equations of Mayer and Tompkins[18] although several assumptions

(Continued on page 32)

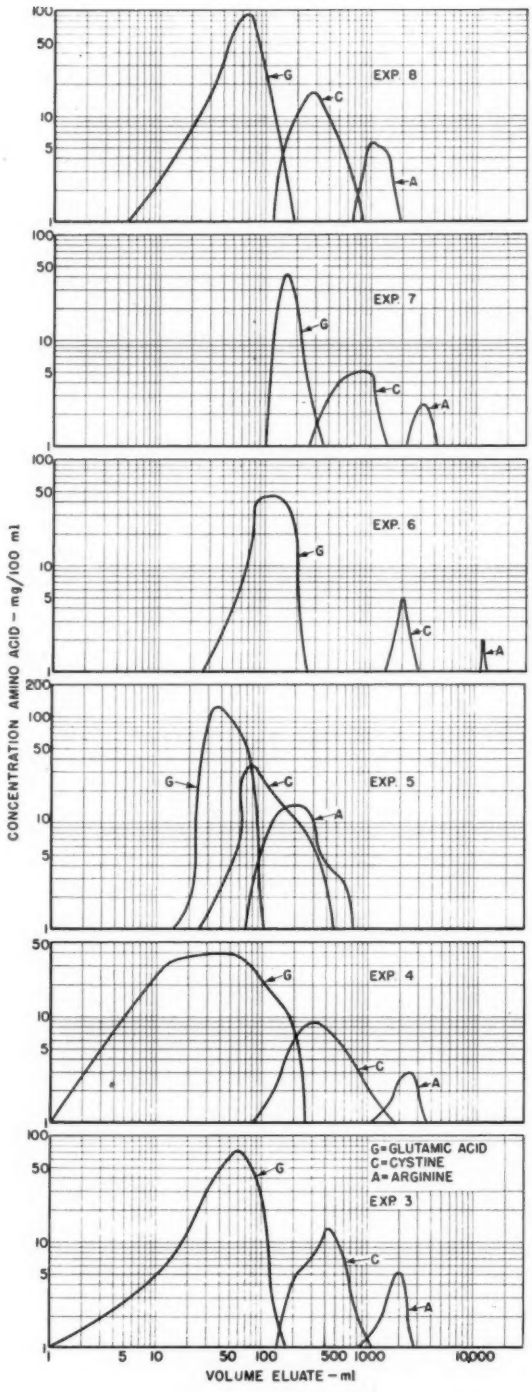


FIG. 2. COLUMN SEPARATION OF AMINO ACIDS

THE ELECTRON DIFFRACTION CAMERA

OLIVER ROW
Electron Microscopist of the Engineering Experiment Station

Oliver Row

Two general methods for studying the structure of matter may be used. In the first, objects are viewed directly, either with the unaided eye or with instruments developed to aid the eye. The second method is indirect. Through the use of instruments and techniques involving interference phenomena, X-ray diffraction, ultracentrifugation, high energy accelerators, polarized light, etc., information is obtained from which conclusions concerning the nature of matter may be drawn. This method gives information about a lower level of observation than so far has been possible by the first method. No instrument is at present available for seeing molecules, or objects in the molecular range of sizes, directly, although the electron microscope is capable of picturing the giant molecules. The indirect methods provide information as to the arrangement of atoms in molecules, atoms and molecules in crystals, shapes and sizes of unit crystals, growth and changes in crystals under varying conditions.

Among the newer instruments in this second group are electron diffraction cameras, one of which is incorporated in the R.C.A. electron microscope at the Engineering Experiment Station so as to permit operation to be shifted from one application to the other in a matter of minutes. Although the theory and practice of electron diffraction antedates electron microscopy, the two techniques have much in common.

When a beam of monochromatic high-velocity electrons strikes a polycrystalline material the atoms in the crystal scatter the electron waves in a regular way. These waves will add in one direction from the crystal or annul in another, depending on whether the crests of the wave fronts from individual atoms are superposed or opposed, and will give reinforced diffracted beams of electrons in directions related to the regular pattern of atoms in the crystal.

In most cases these diffracted beams form cones which will intersect the plane of a photographic plate or fluorescent viewing screen in concentric rings. Figure 1 is a picture of these rings from a sample of bentonite, a clay mineral of wide use. These rings are related to the interplanar spacing of the atoms in the crystalline material by the basic equation for diffraction (Bragg's Law):

$$n\lambda = 2d \sin \theta,$$

where the integer n is the order of reflection, λ the de Broglie wave length of the electrons, d the distance between two adjoining lattice planes, and θ the half angle of the diffracted cones.

For the small angles involved, this reduces to

$$kn\ \lambda\ L = 2dR,$$

where R is the radius of the ring corresponding to the interplanar spacing d, L is the effective specimen-to-plate distance and k is an instrumental constant. When the electron beam is a parallel beam or a diverging beam from a distant source, the ring pattern may be focused on the plate by use of an electron lens. The constant k is related to the index of refraction of the magnetic field of this electron lens and has a value unity for zero field strength.

With the voltage in the R.C.A. electron diffraction camera constant and with the specimen-to-plate distance fixed, this can be further simplified to

$$K = Rd,$$

from which the lattice spacings can be calculated, using measured values of the radii of the rings. By photographing and recording radii of diffraction rings of some material whose lattice spacings have been published, the value of K can be determined. Sodium chloride (Fig. 2) is very often used for this purpose. The calculated value of K is then used with measured ring radii of other unknown materials to calculate their interplanar spacings. This value, owing to the stability of instrumental conditions, is quite constant and does not require calibration each time accurate measurements are desired, varying less than one per cent over a period of several months.

Two types of patterns are generally studied. In the first type, transmission patterns, the electron beam passes directly through the sample giving rings. These correspond to the powder patterns of X-ray diffraction. This type of picture is shown in Figs. 1, 2, 3, 5. All the pictures shown are direct prints from the

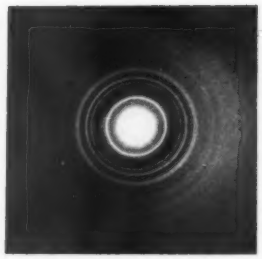


Fig. 1. Bentonite

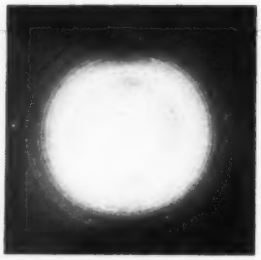


Fig. 2. NaCl

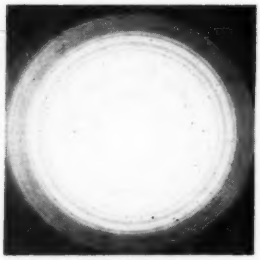


Fig. 3. ZnO

Fig. 4. ZnO (microgr.)

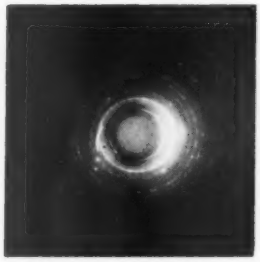


Fig. 5. Insuff. NaCl

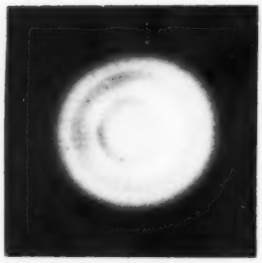


Fig. 6. Parlodion

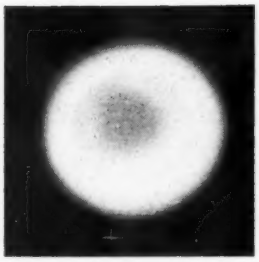


Fig. 7. Formvar

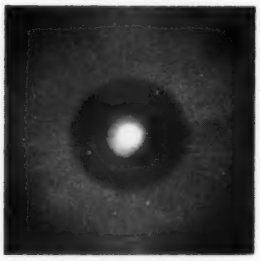


Fig. 8. Carbon

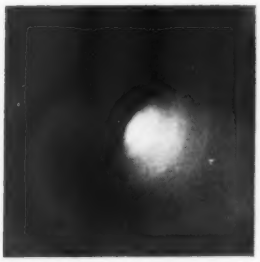


Fig. 9. Brass

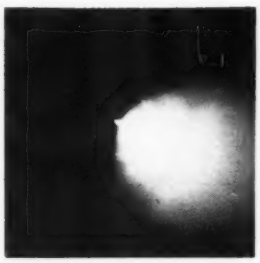


Fig. 10. Aluminum

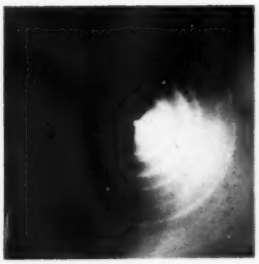


Fig. 11. C. R. Steel

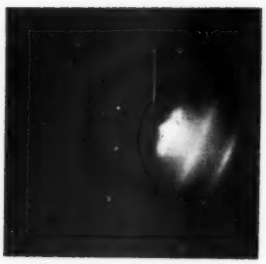
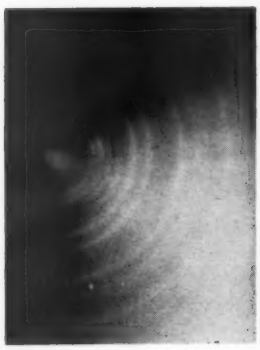


Fig. 12. Steel with Grease



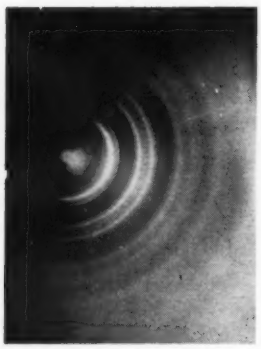


Fig. 13. Progressive Oxidation of Copper (left) to Copper Oxide (right)

negative, in conformity with practice in electron diffraction work. (The practice for X-ray diffraction pictures is to show the rings black on a light background.) To obtain complete rings there must be a completely random arrangement of crystals in the sample. Figure 5, a diffraction picture of sodium chloride in which there were insufficient crystals present, shows a preferred orientation of crystals in the sample. Zinc oxide smoke (Fig. 3)* presents an abundance of sharp rings for calibration or study. Figure 4 is an electron micrograph of the same sample of zinc oxide taken after the instrument has been converted for electron microscopy, and showing its appearance a few minutes after the diffraction pattern of Fig. 3 was studied.

Complex organic molecules present a somewhat different pattern of this type. Since they are essentially noncrystalline (or if they be considered crystalline, with the large molecules themselves constituting very small crystals), they show very diffuse rings. Figures 6 and 7 show patterns obtained from thin films of Parlodion and Formvar, common plastics, with the broadening of the rings. Since specimens for study are usually mounted on thin films of these materials, the patterns must be taken into account in studying electron diffraction pictures. Formvar is presently being used as an insulating coat on wires for electric circuits. Its presence or absence might thus be detected by electron diffraction. Figure 8 shows the pattern of a sample of carbon which is the main constituent of these plastics. The similarity in the ring patterns may be noted, the greater sharpness of the rings of the carbon sample indicating a larger size of the crystals in the sample.

Since high-velocity electrons used in these experiments have no appreciable penetrating power, the study of crystal structure of metals presents a problem in electron diffraction practice. Although some work has been done on such substances as thin gold leaf, ordinarily the preparation of samples is too involved to be practical. However, the difficulty has itself been made use of, to advantage. The electron beam can be reflected from a metal surface penetrating only the outer layers of atoms at the surface and being diffracted by them. This technique produces the second type of patterns, reflection patterns. A special goniometer head has been devised to adjust the specimen so that the electron beam strikes it at a very low grazing angle and passes on to the viewing plate. Figures 9 and 10 show patterns obtained in this way from samples of brass and aluminum, respectively. About half of the pattern has been blocked out by the specimen itself but enough is present to measure the radii of the rings, furnishing all the information necessary.

Electron and X-ray diffraction methods supplement each other and together provide much information with enough overlapping fields to provide comparative checks. In fact, many laboratories employ both methods of study in their work. Calculations of lattice spacings from electron diffraction data agree with X-ray diffraction data to within 0.5 per cent where measurements are made on samples which can be studied by both methods. Some single crystal electron diffraction studies have been made with satisfactory results. An essential difference in the two methods is in penetration. X-rays penetrate through a metal sample and integrate the information throughout the sample. Electrons do not penetrate more than about 500 Ångström units of the metal before inelastic scattering prevents their return to the viewing plate. This fact can be used to great advantage in studying surface phenomena such as crystal structure at the metal surface and changes on the surface under varying conditions. For instance by this technique the presence or absence of a lubricating film or an alloy on a metal surface may be determined qualitatively, and much can be learned about the true nature of lubricating films, tarnish, polish, and etching on metal surfaces. Figure 11 shows the reflection pattern of a sample of steel and Fig. 12 shows the same sample of steel with a thin film of grease on the surface. (In Fig. 12, note that the central spot is more distant from the pattern than in other reflection patterns shown.)

The series shown in Fig. 13 presents first (left), the reflection pattern of a copper surface, in which some preferred orientations may be noted, followed by diffraction patterns obtained at different stages of oxidation of the copper sample.

Studies made through the use of the electron diffraction camera have already contributed to the solution of many scientific problems, and the ease and convenience of obtaining data by this technique will doubtless greatly increase the future use of the instrument.

"Research is regimentation. . . . It is the fundamental particles of nature, however, which are being regimented—electrons, atoms, nuclei, etc.—and we, the research scientists and engineers, are the polit-bureau! By purges, we purify materials to contain molecules all of one kind. By electric and magnetic fields, or other means, we indoctrinate electrons and atoms to a common orientation exhibiting unique properties, such as magnetism or optical polarization. By fearful means and diabolical contrivances, we impel electrons or molecules into conformity with uniform velocities as streams in our electron tubes, cyclotrons, turbines and jet engines. We use catalysts as subversive influences, propagandizing atoms and molecules into particular chemical behavior or union."—K. W. MILLER, "Fun, Facts and Fancies About Research," *Weld. Res. Supp.*, Nov., 1949.

TRIETHYLENE GLYCOL AS A PULPING AGENT AND SOLVENT FOR LIGNIN*

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Professor of Forest Products

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Research Assistant, Engineering Experiment Station

B. L. Grondal

The fact that some organic solvents will dissolve the lignin complex found in wood has been known for many years. As early as 1893, Peter Klason[1] discovered that ethyl alcohol dissolved a portion of the lignin complex if a small quantity of hydrochloric acid was present. Grüss[2,3,4] and others obtained the same result by using either methyl, butyl or benzyl alcohols, or ethylene glycol. Engel and Wedekind[5] obtained a patent in 1933 on the use of dioxane as a pulping agent for wood. That phenols could be used to extract the lignin complex was first noted by Bühler[6] in 1897. Peterson and Wise[7] were granted a patent in 1940 on the use of monoethanolamine as a pulping agent. The catalytic action of hydrochloric acid when added to acetic acid to form a liquor that could be used in the pulping of wood was investigated and suggested, in 1942, by Schultz and Knackstedt.[8] The use of chloral hydrate and a catalyst as a possible pulping agent was investigated by Alfred Ogait[9] in 1944.

Seemingly, none of the solvents that have been mentioned has advanced beyond a laboratory stage. The alcohols that have been mentioned do not completely dissolve the lignin complex. Furthermore, unless the wood is in a state of very fine subdivision, the prolonged cook that is required militates against their use on a commercial scale. The pulp resulting from dioxane digestions proved to be poor, and as dioxane is poisonous, its use is attended with considerable danger. Phenols remove the lignin complex from wood quickly and completely, but strongly degrade the cellulose. Chloral hydrate was found to produce pulp of high quality, but the extracted lignin complex contains a large amount (15 per cent) of chlorine. Up to the present time, no organic liquid has proved to be a practical pulping agent for wood.

Piotr Zenczak

In all commercially successful pulping processes that are in use today, water solutions of inorganic compounds are used. These are relatively inexpensive, and they produce good pulp. However, the yield of pulp from wood is, by weight, approximately 50 per cent, and there is an appreciable loss of fiber strength. The dissolved lignin complex and carbohydrates resulting from these processes constitute either a nuisance in the form of a waste liquor that presents a difficult disposal problem, or, in the case of two processes, entails the use of a costly recovery system in which there is merely a moderate heat-gain. Therefore, the search for a better method for the utilization of wood in the production of pulp is still a problem of great importance, and every possibility of developing a new method that will give higher yields and that may permit the profitable utilization of the extracted lignin complex should be investigated.

During the course of a research on the pyrolysis of wood at the Forest Products Laboratory of the University of Washington, the writers found that when wood is heated to a temperature of 250 degrees C, while immersed in triethylene glycol ($HOCH_2CH_2OCH_2CH_2OCH_2CH_2OH$) it undergoes complete defibration, even when no catalyst is present. Blocks of Douglas fir 2 in. by 3 in. by 1½ in. in size were cooked, and in a period of two hours, very uniform defibration resulted. This suggested the further investigation of the use of triethylene glycol as a solvent for the lignin complex at a lower temperature. At a temperature below 200 degrees C, no defibration occurred, and this indicated that it was possible that some compounds, probably organic acids, were formed in the wood at the higher temperature and

* A preliminary report.

that these exercised a catalytic influence on the reaction. When a catalyst was added, complete defibration of the wood was obtained at a temperature as low as 115 degrees C. It was found that the minimum quantity of acid catalyst required is equal to .03 per cent to 0.4 per cent of the air-dry weight of the wood. The ash content of the wood must be taken into consideration because wood contains basic compounds which will reduce the acid catalyst. Besides acids, mineral chlorides are also effective as catalysts. Aluminum chloride (Al_2Cl_3) in the right proportion, coupled with proper control of the cook, seems to be most effective in promoting the solution of the lignin complex. Furthermore, the lignin complex recovered from the solution appears to have valuable adhesive properties which are controlled mainly by the pH.

When a maximum yield of pulp of high strength is demanded, hydrolysis of the wood must be avoided so that the hemicelluloses will be left in the fibers. This is especially desirable in the case of species which have short fibers, as the bonding properties of hemicelluloses permit the manufacture of stronger paper. Triethylene glycol containing the optimum amount of catalyst gives satisfactory defibration with very little damage to the carbohydrates. As a result, a higher yield of pulp of optimum quality can be obtained. When pulp is to be used for the production of viscose, a high alpha cellulose content is essential. This can be accomplished by hydrolyzing the wood in a 0.5 per cent hydrochloric acid solution and then extracting the lignin complex with the triethylene glycol. By the use of this method, very uniform defibration is obtained. In both instances, the lignin complex that is recovered contains only small quantities of carbohydrates, and therefore there is no possibility of a condensation occurring between these two substances. This may be one reason why the lignin complex has more valuable properties than that obtained by other methods.

Outline of Procedure Employed

Wood chips were heated to a temperature of 125 degrees C while immersed in four parts by weight of triethylene glycol containing aluminum chloride as a catalyst. After all water had been driven out of the wood, the lignin complex began to dissolve very rapidly and defibration occurred in from one to two hours. Stirring improved the action of the solvent and produced more uniform defibration, but satisfactory results were obtained even without stirring. The cook was conducted in an open vessel at atmospheric pressure. It was found that by the use of pressure, the amount of solvent needed could be reduced to 1.5 or 2 parts to one part by weight of the wood. Upon completion of the cook, the solvent was drained from the soft and partially disintegrated chips. These were then subjected to pressure in a hydraulic press for further recovery of the solvent, and after pressing were washed with warm water and finally dried at 60 degrees C in an oven. The dark brown glycol thus recovered was then diluted with 1.0 to 1.5 parts of warm water, depending upon the concentration of the lignin complex in the solvent. This caused most of the lignin complex to precipitate. After filtration to recover all of the precipitate, it was washed with warm water and dried at 80 degrees C, whereupon it formed a finely divided, light yellow powder. To recover all of the lignin complex, traces of sodium chloride were added to the diluted filtrate, which was then refiltered.

The pulp that was obtained was very light in color, and although no tests were made, it appeared to have a high fiber strength. No reducing sugars were found in the lignin precipitate after it had been hydrolized with a 0.5 per cent solution of HCl in water. As the lignin complex appeared to exhibit adhesive properties when used as a thermosetting glue, plywood specimens of Douglas fir were prepared. When tested in the usual manner, dry, a wood-failure of 60 per cent with a shear strength of 250 psi resulted. Moreover, the lignin complex when used in this manner appeared to be as water resistant as commercial phenolic resin plywood glue. Preliminary tests in using this substance as a binder in the preparation of wood-fiber "hard-board" by the so-called "dry" process have given promising results.

Additional experiments have been conducted in which a diethylene glycol monoethyl ether is used instead of triethylene glycol. Satisfactory defibration has been obtained, but the recovered lignin complex has different properties—a higher melting point, and inferior adhesive properties. The fact that Gray, King, Brauns and Hibbert[10] in their investigation of ethylene glycol found that only 40 per cent of the lignin complex could be removed from wood with this solvent, indicates that 1, 2 glycols behave differently. Further studies on the use of triethylene glycol as a pulping agent are currently in progress.

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Photoelastic Analysis of a Turbine Rotor *

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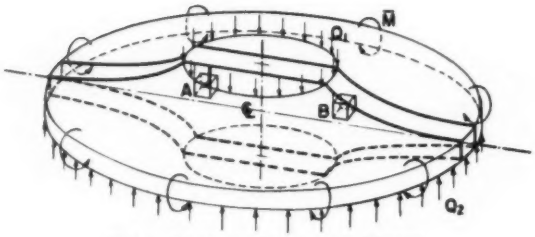

FIG. 1. LOADING SYSTEM ON MODEL

A SINGLE DISC of a built-up multistage turbine rotor is subjected to a complicated loading system because of temperature gradients, centrifugal forces, radial thrusts, and many other factors. The effect of some of these loads is to subject the turbine rotor to a uniform bending moment and axial force around the periphery of the disc, and by applying the theory of elasticity, the stresses due to these loadings can be calculated for rather simple profiles. To accomplish an experimental check of the stresses caused by the loading shown in Fig. 1, the frozen stress pattern method of photoelasticity was chosen.

Since, under elevated temperatures, the modulus of elasticity of the material is greatly reduced, the deformations become large, requiring the anticipation of the strains due to load, in manufacturing the unloaded model. Fig. 2 shows the unstressed saucer shape of the rotor model with allowance machined in for the anticipated strains, a shape determined from an analytical calculation of the deflection curve for the original rotor profile.

Fig. 3 shows the final shape after the model under load has been carried through the proper annealing cycle to fix the fringe pattern. This may now be sawed up with no effect on the pattern and observed from any desired orientation. Fig. 4 is the isochromatic pattern of this diametrical section after sawing. Fig. 5 is a plot of the fringe order. The fringe order, which is proportional to the boundary stresses since one principal stress is zero, already has furnished a good qualitative check with previously made analytical stress calculations for this section.

*Based on data from Experiment Station Project No. 47, "Photoelastic and Analytical Stress Analysis of a Turbine Rotor Subjected to Normal Loading," under the joint supervision of the writer and Prof. W. B. Nordquist, with Ke Sang Chun as research fellow in the Engineering Experiment Station. The project is nearing completion.

FIG. 2. ORIGINAL SHAPE OF MODEL WITH ALLOWANCE FOR ANTICIPATED DEFLECTIONS MACHINED IN

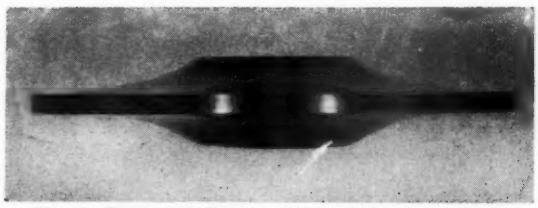

FIG. 3. DEFLECTED MODEL AFTER ANNEALING CYCLE SHOWING FINAL DESIRED SHAPE

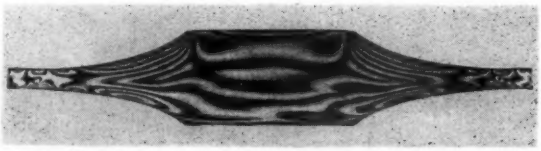

FIG. 4. FROZEN FRINGE PATTERN FOR DIAMETRAL SLICE

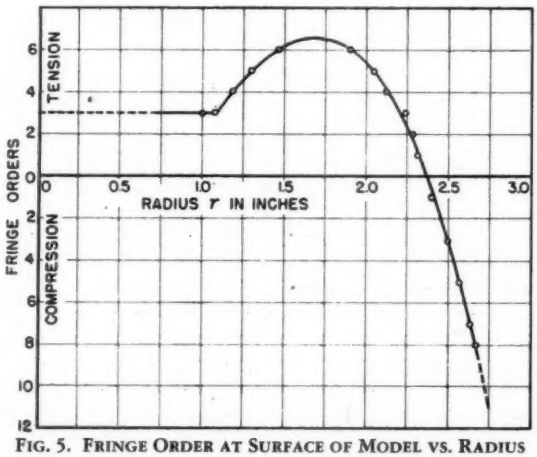

FIG. 5. FRINGE ORDER AT SURFACE OF MODEL VS. RADIUS

The Two-Year Graduate Degree in Engineering

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IN ENGINEERING, as in other fields, the continually increasing body of knowledge and the prevalence of college graduates leads many students to seek education beyond that of the bachelor's degree. Traditionally, the schools of this country offer two advanced degrees, the master's based on a minimum of one year of graduate work, and the doctorate, which usually takes three years with much of the emphasis on research. The engineering professional degree, also common, is usually given upon presentation of a suitable thesis and an experience record of about five years in responsible engineering work. Thus the professional degree differs greatly from the academic degrees of master and doctor earned in residence at the school, and the emphasis is on professional attainment rather than upon earned academic credit. In fact recognition of engineering training and experience by the state engineering license laws lessen the need for the professional degree, and some schools may be inclined to drop it.

The Two-year Degree

For twenty years or more, several schools in this country have offered a two-year graduate degree in engineering. The list includes the California Institute of Technology, Harvard, Stanford, the University of California, and the Massachusetts Institute of Technology which has recently adopted the two-year program. A number of other schools are reported to give similar degrees, but a careful search of their catalogs does not confirm this report.

The purpose of the degree is nicely stated in the M.I.T. catalog as "a program leading to a higher level of professional engineering competence than is required for the master's degree without emphasis on creative research which is characteristic for the doctoral program." In most of the listed schools the course work in the major field for the two-year degree is essentially that required for the doctorate.

The requirements for the degree rather uniformly include two years of work and a thesis—approximately twice the master's requirement. The thesis is expected to be of higher level than that of the Master of Science but the research emphasis does not approach that of the doctorate.

Naming of the Degree

For the two-year degree, California, C.I.T., and M.I.T. uniformly employ the titles of Mechanical Engineer, Civil Engineer, etc. These titles have the disadvantage of confusion with similar professional degree titles. Thus one man uses the title, Mechanical Engineer, (M.E.) to represent two years of academic graduate work, while for another it represents engineering field experience plus a thesis based on original work. Stanford uses the title, Engineer, without designation of any branch. This offers a partial break from the designations employed for the professional degree, and with universal adoption the title could acquire dignity and definite meaning.

Harvard's term, Master of Engineering, for two graduate years, avoids confusion with the professional degree but adds to the confusion of master's degrees such as Master of Science in Electrical Engineering, Master of Electrical Engineering, Master of Science in Engineering, etc., which usually represent one-year degrees but sometimes stand for two years. The student, too, may feel some disappointment in merely collecting an added master's degree for the second year of work. How much better to have some distinctly different and interesting title to capture the imagination!

One possible title that has not yet found use in this country is that of Diploma Engineer. This European designation (*Diploma Ingenieur*) stands for technical academic achievement similar to that represented by two years of graduate work in this country. The degree has acquired a definite meaning in Europe and could become accepted in the United States. Use of the name would make a sharp break from the present; such a step could well be taken now while only a few schools offer two-year degrees.

The Role of the A.S.E.E.

One function of the American Society for Engineering Education is that of coordinating the activities of the various engineering colleges through the establishment of recommended practices. A single school, for example, would find it difficult to adopt the title of Diploma Engineer because of the prospect that other schools might not follow suit. On the other hand, the adoption of a master designation or the engineering degree only adds to the present confusion unless some standardization is attempted. Clearly, action by an authoritative body, such as the A.S.E.E., to establish a recommended practice would encourage schools seeking to establish new graduate degrees, and might persuade schools already using other designations to conform to the adopted practice.

THE MECHANICS OF FROST ACTION ON HIGHWAYS*

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R. H. Meese

Introduction

Frost heave, of course, is the expansive process that takes place in freezing weather and results in the heaving of the roadway surface. When thawing occurs, it leaves the heaved soil in a supersaturated condition, resulting in frost boils or loss of bearing capacity. In the freezing process there is likely to be differential heaving, warping of the roadway surface, and, if severe, cracking of pavements. Traffic during and immediately after the thawing period may cause the complete destruction of flexible pavements. The intent of this discussion is to outline the mechanics of frost action and to review briefly the reports of investigations of possible means of dealing with the problem.

Physical Principles

The fundamental principle of frost action is that the heave is caused primarily by the growth of ice in segregated lenses. For an analogy one might imagine the soil to contain a number of balloons. The heaving process then would correspond to an inflation of the balloons with water drawn up from below. The soil proper, being entirely between the balloons, would remain at essentially its original moisture content. The thawing process would correspond to the progressive bursting of the balloons, starting from both top and bottom of the heaved stratum. The effect of the expansion undergone by water in the freezing process can be dismissed as relatively unimportant for three reasons. First, the expansion, about 9 per cent of the volume of the water, would produce an expansion of only about 3 per cent of the total volume of soil or a heave of about one-third inch per foot of frost penetration, while heaves up to 15 or 20 times this amount have been observed; second, it cannot account for the soupy condition of the soil in frost boils after thawing; and, third, examination of heaved soils shows the ice to be present in segregated layers or lenses.

Theories explaining frost action under natural conditions of exposure require the existence of a state of capillary saturation and the presence of some fine soil particles. The function of the fine particles is twofold: first, supplying the capillarity, or force to draw water up above the ground water table and second, setting up forces of adsorption on the water in surrounding films and fine voids that lower the freezing point. The result is that there is unfrozen water in the frost zone at a temperature below the normal freezing point. Where this water comes in contact with ice that has formed from free water in the larger voids, additional crystallization takes place. When this happens, an upward flow of water is induced, and the ice grows into lenses. These lenses continue to grow at a rate which, under constant temperature conditions, depends on the size of and pressure upon the lens or on the rate at which water can be supplied from below. The force which moves the water is associated with the capillarity of the soil; thus the rate of water supply depends on the capillarity and permeability of the soil and on the elevation above the water table.

Factors Influencing Frost Action

This concept of frost action serves to explain the effects of the governing factors of moisture, exposure, and soil properties that have been consistently observed by investigators. The influence of these factors is as follows.

Moisture. In order to have frost action the soil must be in a state of capillary saturation. This requires only that the water in at least the finer voids must be continuous with the water below the water table so that water may be drawn upward during the heaving process. This condition may be satisfied by an amount of moisture much less than that required for complete saturation and ordinarily may be presumed to exist. Raising of the water table accelerates the potential rate of capillary flow, and an increase in the degree of saturation would also tend to increase the amount of heave. Field observations associate the greatest heaving with high water tables and rainy periods preceding the freeze.

* Presented before the Third Northwest Conference on Road Building, Seattle, February 8, 1950.

Exposure. Experiments by Casagrande at Cambridge, Massachusetts, in the winter of 1928-29 under natural exposure, showed a remarkable correlation between cumulative daily temperature deficiency and both heave and depth of frost penetration. It now seems to be standard practice in frost action investigations to measure exposure in terms of cumulative temperature deficiency (degree-hours or degree-days of freezing), and it is well established that the amount of heave increases with the amount of exposure.

Soil properties. The soil properties affecting frost heave are capillarity and permeability. Some work has been done in correlating these properties with the amount of heave. On the basis of capillarity, Dr. Gunnar Beskow, State Road Institution of Sweden, classifies soils as follows:

Capillary head	
Less than 1 m	safe
One-half m to 10-20 m	very hazardous
Over 20 m	slightly hazardous

Soils with a capillary over 20 m are relatively fine grained and impervious, and this impedance to the flow of water and perhaps the possibility that an important fraction of the water above the frost line remains unfrozen in very small voids tends to reduce the heave to a moderate and frequently acceptable amount. In general, and particularly in this country, the preference has been to determine the susceptibility on the basis of grain size and other identification properties. The conclusion of Casagrande's investigation was that considerable ice segregation (hence, heave) is to be expected in graded soils containing over 3 per cent of grains smaller than 0.02 mm. Beskow has similar rules. It has become common practice to classify soils according to a system in groups on the basis of identification properties, and the degree of susceptibility to frost action has been established for the group. Such a classification system was described by Mr. Humphres.* On the basis of soil texture it may be said that frost action is greatest in silty sands, becoming smaller as the grain size is decreased and being moderate or slight in the clay range. Clean, coarse-grained soils are not subject to ice segregation.

Frost heave, then, may be summarized as follows:

1. Frost heave is the result of the formation of segregated lenses of ice.
2. It takes place in soils that have more than a slight capillarity and is worst in soils that also are relatively pervious.
3. It requires a state of capillary saturation which usually is bound to exist in susceptible soils, and is increased by a greater moisture content and by a higher water table.
4. The amount of heave increases with the coldness and duration of the freezing period.

Control of Frost Heave

The most common method of controlling frost action is to provide a subbase of nonsusceptible material. The depth of the frost-free material placed varies from several inches to two or three feet or to the full depth of frost penetration. In cases of deep frost penetration a depth of frost-free subbase equal to about one-half the depth of frost penetration is quite widely used. In general if the subbase does not extend to the full frost depth it should be drained and perhaps be protected from the ingress of fine-grained soil from below by a filter layer. Extending the blanket across the entire cross section to allow drainage toward each side seems to be the preferred practice. In addition to eliminating or reducing and evening the heave, this construction serves the important purpose of expediting the escape of excess water which is released by thaw from above, and which is otherwise prevented from escaping downward by the frozen condition below. At bridge approaches and culverts it is desirable to have a gradual transition in blanket thickness to the full depth of frost penetration in order to minimize differential heaving.

Another approach is by drainage. In general the frost-hazardous soils have enough capillarity so that it is not possible to prevent capillary saturation by lowering the water table a normally practicable amount. However, the amount of frost heave is roughly proportional to the depth of the water table, and the lowering of the high water tables to moderate depth by drainage effectively reduces the amount of heave. Installation of pipe drains beneath the pavement is generally regarded as undesirable because of the differential heaving likely to be produced.

A third possibility is the use of admixtures in stabilized subgrades, extensive investigation of which has been carried out by the Joint Highway Research Project of the State Highway Commission and Purdue University of Indiana. Admixtures may have the desirable effect of decreasing the permeability and capillarity and lowering the freezing point and, under suitable conditions, are effective in reducing frost heave. In our so-called mild coastal climate the antifreeze type, such as calcium chloride, might offer excellent possibilities where leaching conditions are not too severe.

Other possibilities that have been suggested include interception of capillary flow of moisture below the frost line by means of an impervious blanket

* "The Soils Engineer in Highway Work," a paper presented by Herbert Humphres before the Third Northwest Conference on Road Building, Seattle, February 6, 1950.

or by a blanket of material of very low capillarity, and the use of heat-insulating material, such as straw, below the base course to reduce the frost penetration. These methods are seldom or never used in this country.

Experience and analysis have shown that frost action is definitely governed by three factors: soil properties, moisture, and exposure. Methods of control, therefore, must consider all of these factors and control one or more of them.

The University Research Foundation

INTEREST in the University of Washington Foundation for Research was stimulated this year by a statement of the University's patent policy as approved by the Board of Regents. According to this statement, the Foundation is to be given patent rights to research and inventions developed with University aid or facilities, but staff members will participate in profits on inventions or ideas which they develop.

Officers of the Foundation met last March with University officials to discuss a proposal to enter an agreement with the Research Corporation, of New York, a patent and research foundation originally conceived by the inventor of the Cottrill precipitator for smoke abatement. On April 24, the trustees discussed and approved the general set-up of the plan. Terms of the plan which would provide special patent and licensing assistance in cases not handled by the Foundation itself, are being worked out.

The University Foundation, a nonprofit organization, has made efforts to accumulate funds only for its prosecution of patents or for the special studies needed before the patent application can be presented. It has used gifts or funds from special sources, when necessary, to advance sound and patentable projects, but it is not designed to make money and it functions solely as a spokesman and agent for the University worker whose research leads him to a new device or process.

The Foundation has examined scores of ideas, including those for new athletic equipment, simplified spelling, commercial alcohol from waste sulphite liquors, cork from Douglas fir bark, and wind-tunnel devices.

The patent procedure, however, can become very complex and costly, especially when matters of legal right or infringement are involved. Furthermore, most of the patentable ideas evolved each year would fail to earn their patent costs, much less return any profits to their inventors. Even "successful" patents rarely return more than nominal sums and only in rare cases are earnings of spectacular size.

When the Foundation receives a possible patent idea from the inventor, it immediately calls in two experts to assess the plan and to discuss with the inventor the market, the need, the economic factors, or the potential refinements. With the inventor, the experts work out for the Foundation a recommendation based on the survey. If the idea seems worth pursuing, the Foundation employs a patent attorney to assist the inventor to draft his specifications. At any of these points there may be changes or questions requiring more study. If the basic idea still has survived, or if aspects of it seem worth preserving, the Foundation initiates application for patent. If special funds are necessary, the Foundation will endeavor to get them. Meantime, it has worked out with the inventor an agreement providing for fair share of potential income. This minimum share to the inventor is 20 per cent, even in cases in which the research was conducted entirely with University aid or facilities. The inventor's share is larger in individual instances. If marketing and promotion finally are indicated, the Foundation will undertake the issuance of licenses to qualified industrial or business organizations.

The statement of policy also includes the following provision:

"An invention in which the University has no vested interest, i.e., one which is developed by a faculty member on his own time and without the use of University facilities, may be voluntarily submitted by the Faculty member to the Foundation for consideration as to its patentability and for subsequent processing and exploitation if accepted. In such case, the inventor will participate in the net profits derived from the patent on a basis mutually agreeable."

The Foundation originally was organized at the University on February 26, 1942, and incorporated on March 27 of that year. It was set up largely on alumni initiative, and the personnel of the board includes both University officials and alumni prominent in business and industry.

Hill and Dwinnell Author Texts

ELECTRONICS IN ENGINEERING. W. Ryland Hill. New York. McGraw-Hill Book Company, Inc., 1949. 269 pp. $3.50.

Chemical, civil, mechanical, and aeronautical engineers, along with other workers in scientific fields, who are making increasing use of electronic instruments and techniques, often find that their training in physics and electrical engineering has stopped at a point a little short of understanding the fundamental principles behind these important tools.

By building on the sound background common to workers in most scientific fields, *Electronics in Engineering* explains the fundamental principles of electronics in a book of surprisingly small size. This has been accomplished, not by over-simplification, but by beautiful organization of the material and a firm faith in the principle that one picture is worth a thousand words. The graphic approach prevails, with over 200 figures, yet mathematics is used freely where necessary. The two approaches are frequently linked by analogies to similar problems in mechanics and by working out practical examples. Though intended as a text for a survey course in electronics, the book should be found very valuable for unsupervised home study, and for ready reference in the laboratory.

Chemical engineers, particularly, will find the material on rectifiers complete and straight-forward. The discussion of oscillators is pointed directly toward applications in dielectric and induction heating. Amplifier theory is sufficiently detailed to include a chapter on feedback, that important key to successful instrumentation. The two tools of electronics which have found the widest use and probably the most careful development warrant a chapter each. These are the cathode-ray oscilloscope and the vacuum-tube voltmeter. Notable, too, is the chapter on transducers. Mechanical and civil engineers will find the material on strain gages in a form suitable for immediate use.

In sharp contrast to the popular and how-to-do-it type of book, this one has two very important qualities: (1) it has sufficient rigor that it may be quoted freely when a technical paper is being prepared and (2) it will give scientific investigators considerable confidence when moving on to works of more detail. In fact, the only criticism this reviewer can offer seems to be the lack of a suitable bibliography to assist the nonelectrical engineer in pursuing the topic of his interest through the confusing maze of electrical engineering literature.

W. E. Rogers

PRINCIPLES OF AERODYNAMICS. J. H. Dwinnell. New York. McGraw-Hill Book Company, Inc., 1949. 391 pp. illus. $5.50.

With the publication of this book, Professor Dwinnell has succeeded in bringing to students and teachers a well-organized and executed text on the fundamentals of aerodynamics. There are many features which are worthy of note, and one is impressed by the obvious care taken to present the material in a fashion which is easily understood by the student and lends itself readily for use as a classroom text. From the teaching standpoint the frequent use of examples and the copious supply of problems will serve to further enhance its value. A complete nomenclature is provided and great care is taken to define symbols as they are introduced and used throughout the text. Also, a representative, though not extensive, bibliography at the end of the book will provide students with adequate reference material.

A basic preparation in general college physics and mathematics is prerequisite for a thorough understanding of the material presented. The author follows the generally accepted procedure of presenting first the fundamental principles of fluid mechanics, followed by a treatment of the various applications of aerodynamics to the airplane of its components. Consideration of types of aircraft other than conventional is omitted except for a brief discussion in Chapter 3, entitled "Aeronautical Nomenclature." The treatment given the subject of compressibility is especially timely in this age of supersonic flight. Effects of Mach number on the forces on an airfoil are examined in the light of theory and experiment. Also, the three-dimensional phenomena associated with air-foils of simple planform are discussed and representative data are given.

Taken as a whole, the book admirably fulfills its purpose and that of its author: to present an introduction to some of the more important theoretical and practical aspects of aerodynamics.

L. B. Gratzer

CORRECTION

In the April, 1950, issue of *The Trend* the footnote on page 31 should appear as a part of the footnote on page 27 and refer to the article, "A New Method of Wood Pyrolysis."

SEPARATION OF AMINO ACIDS BY ION EXCHANGE

(Continued from page 20)

made in developing these equations are not met by present experimental conditions. The pertinent equations are:

$$C = \frac{\text{Total eluate volume to } Z_{max}}{V}$$

$$= (K_d)\left(\frac{\text{g resin in a plate}}{\text{ml soln. in a plate}}\right) \quad (3)$$

$$\frac{Z_{max}\,V}{Wp} = \frac{1}{[2\pi pC\,(1+C)]^{1/2}} \quad (4)$$

where Z_{max}=maximum concentration of amino acid in eluant, mg/liter; V=volume occupied by liquid in column, liters; W=total weight of amino acid present, mg; p=number of plates; C=distribution of solute as weight of amino acid on resin per unit amino acid in solution; K_d=partition coefficient of amino acid between resin and solution.

Values of C shown in Table III are roughly constant for a particular amino acid and a particular eluant, and this should be the case since this quantity represents only the product of the partition coefficient and the liquid/resin ratio. It is seen that C varies inversely with acid concentration which thus reflects the influence of hydrogen ion concentration on the partition coefficient, i.e., increase in hydrochloric acid concentration brings about increase in the proportion of amino acid in the solution phase. Attempts to correlate values of the equilibrium constant K_d, calculated from these column experiments, through C, with the K_d calculated from the equilibrium experiments, have not been successful, no doubt because the Rothmund and Kornfeld equation cannot in these cases be extrapolated to the high hydrogen ion concentrations used in column separation experiments.

The calculated numbers of plates in the several experiments are found to be widely variable. In making this calculation, there are employed experimental values of C and also of the maximum concentrations observed for each amino acid. Since the latter quantities are strongly influenced by channeling and also by flow rate (cf. Experiments 3 and 4), which brings about departures from the assumed point conditions of equilibrium, the rather wide variations may perhaps be understood. No attempt is made at this time to deal theoretically with variations in number of Mayer and Tompkins' plates. However, for convenience in comparison, the height of resin column per plate has been calculated for the several cases, and is given in Table III.

SUMMARY

1. The equilibrium distribution of glutamic acid, cystine, and arginine between aqueous solution and the ion exchange resin, Dowex 50, has been determined under certain conditions, and results are correlated by the Rothmund and Kornfeld equation.

2. Preliminary experiments on separation of these three amino acids by ion exchange chromatography have been carried out and attempts have been made to treat the data by use of the Mayer and Tompkins equations.

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HYDROELECTRIC POWER IN THE NORTHWEST

(Continued from page 9)

consumption exists in the Northwest. Corrective steps have been taken, but because of the time delay between planning, construction, and eventual operation, the shortage will continue for at least seven or eight years. Output of the generators installed so far in the federal three-phase development program for the Columbia Basin has not met the unforeseen demand for power in this region. At the present time the government is the only agency which seems willing to undertake the necessary program.

The cooperative plan of the Northwest Power Pool has made an important contribution toward meeting the demand of the region by providing a substantial "effective" capacity to members of the system.

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